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Titles of 954 technical articles are listed on the subject of toxicological, physiological and metabolic effects of stable and radio-labelled chemical species of metal cations to marine, estuarine and freshwater flora and fauna. Each reference was annotated and subsequently indexed by metal, by taxa, and by author, in cumulative indices which encompass this volume and the initial volumes in this series (Eisler, R. 1973. Annotated bibliography on biological effects of metals in aquatic environments [No. 1-567]. U.S. Envir. Prot. Agen. Rept. R3-73-007: 287 pp; Eisler, R. and M. Wapner. 1975. Second annotated bibliography on biological effects of metals in aquatic environments [No. 568-1292]. U.S. Envir. Prot. Agen. Rept. 600/3-75-008: 400 pp).

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THIRD ANNOTATED BIBLIOGRAPHY ON BIOLOGICAL EFFECTS OF METALS IN AQUATIC ENVIRONMENTS

[No. 1293-2246]

by

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FOREWORD

The Environmental Research Laboratory of the U.S. Environmental Protection Agency is located on the shore of Narragansett Bay, Rhode Island. In order to assure the protection of marine resources, the laboratory is charged with providing a scientifically sound basis for Agency decisions on the environmental safety of various uses of marine systems. To a great extent, this requires research on the tolerance of marine organisms and their life stages as well as of ecosystems to many forms of pollution stress. In addition, a knowledge of pollutant transport and fate is needed.

This report lists 954 titles of selected articles from the world technical literature on the subject of toxicological and physiological effects of toxic cations and heavy metals to aquatic biota. Each article is annotated at length, and cross-indexed by metal, by taxon, and by author in cumulative indices that include the two preceding volumes in this series. It is part of a continuing effort by this laboratory to construct a meaningful platform for use in future research in this area, and for providing a sound data base in updating of existing water quality criteria for metals in freshwater and marine environments.

Eric D. Schneider,
Director

ABSTRACT

Titles of 954 technical articles are listed on the subject of toxicological, physiological and metabolic effects of stable and radio-labelled chemical species of metal cations to marine, estuarine and freshwater flora and fauna. Each reference was annotated and subsequently indexed by metal, by taxa, and by author, in cumulative indices which encompass this volume and the initial volumes in this series (Eisler, R. 1973. Annotated bibliography on biological effects of metals in aquatic environments [No. 1-567]. U.S. Envir. Prot. Agen. Rept. R3-73-007: 287 pp; Eisler, R. and M. Wapner. 1975. Second annotated bibliography on biological effects of metals in aquatic environments [No. 568-1292]. U.S. Envir. Prot. Agen. Rept. 600/3-75-008: 400 pp).

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SECTION I

INTRODUCTION

As was true in the two preceding volumes in this series, published as EPA reports R3-73-007 and 600/3-75-008, respectively, the present account lists journal articles and reports resulting from laboratory and field investigations on toxicological, physiological and metabolic effects of stable and radioactive species of heavy metals and other cations to aquatic life. Most of the references listed herein were published within the five year period between 1971 and 1976, but a substantial minority have been in print for some time and have only recently become available to us. For this issue we selected articles which emphasized the following response parameters: survival; growth; reproduction; behavior, bioaccumulation; retention; translocation; histopathology; baseline data on elemental composition; changes in exogenous salt content on responses including internal changes in salt balance of body fluids and tissues; interaction effects of metals and their salts in combination with other substances; and finally, modifying effects of boitic and abiotic factors on all parameters examined.

As more information becomes available, and future volumes in this series are produced, it is hoped that contamination standards for each metal can be established administratively at levels which neither jeopardize the stability of aquatic ecosystems nor present a public health hazard via aquatic food chains.

SECTION II

REFERENCES

References are arranged alphabetically by author and then numbered. Each reference is indexed by metal(s), by author(s) and by taxonomic group(s) in the index (Section III).

1293. Aarkrog, A. 1971. Radioecological investigations of plutonium in an arctic marine environment. Health Physics 20:31-47.

On 21 January 1968, a B-52 bomber from the U.S. Strategic Air Command crashed on the ice in Bylot Sound 11 km west of Thule Air Base, Greenland. By impact with the ice the chemical explosive in four unarmed nuclear weapons carried by the aircraft detonated, and some kilograms of plutonium were released to the environment. Most of the contamination was confined within a drop-shaped area of approximately 700 x 150 m stretching southward from point of impact. Bomb debris, wreckage from the plane and the surface layer of the contaminated snow in the drop-shaped area were removed by the U.S. Air Force during the first few months after the accident and shipped in the autumn to the Savannah River plant in the United States. During summer of 1968, soil, water and biota were collected from the vicinity of the accident. Elevated levels of plutonium, present mainly as insoluble plutonium oxide particles, were found in the marine environment of Bylot Sound. Plutonium concentration in sea water increased by a factor of two. In sea bottom sediments the increase was one order of magnitude and two orders of magnitude beneath the impact area. Bivalves showed increased levels up to a distance of 15 km from the crash area. The median level in bivalves was one order of magnitude above the fall-out background, and in the crash area it was three orders above. Macoma contained more plutonium than the other species of bivalves. Crustaceans, polychaetes, and echinoderms showed median levels about 1000 times the fall-out background. Fish living near the sea bottom, e.g. the Greenland halibut, contained plutonium levels one to two orders of magnitude above the fall-out background. The other samples: zooplankton, sea plants, sea birds, seals and walruses did not contain plutonium levels significantly different from the fall-out background. Plutonium was not detected with certainty in human urine samples.

1294. Abbott, N.J., R.B. Moreton, and Y. Pichon. 1975. Electrophysiological analysis of potassium and sodium movements in crustacean nervous system. Jour. Exp. Biol. 63:85-115.

Estimates were made on half-times for Na+ and K+ entry and efflux from extra-axonal space in peripheral nerve and central nervous connectives of the marine crab Carcinus maenas, and freshwater crayfish Procambarus clarkii; results were qualitatively similar. Peripheral nerve showed no evidence for diffusion barriers, K+ entry and efflux being rapid, and proceeding at comparable rates. In connectives, K+ entry was extremely slow, with a half-time > 100 min, while K+ efflux was relatively rapid ($T\frac{1}{2}$ = 6 min). Na+ movements were less restricted, but entry was more rapid than efflux. Potassium experiments were compared with behavior of a theoretical model system. Evidence is presented for diffusional restriction to K+ at connective perineurial layer; this process involves changes in premeability or activation of an ion pump in perineurial layer.

1295. Abdullah, M.I., J.W. Banks, D.L. Miles and K.T. O'Grady. 1976. Environmental dependence of manganese and zinc in the scales of Atlantic salmon, *Salmo salar* (L) and brown trout, *Salmo trutta* (L). Freshwater Biol. 6:161-166.

Manganese and Zn concentrations in scales of salmon and trout from North Wales showed significant dependence on environmental levels. In Lake Bala, mean dissolved Mn was 23 ug/l and Zn 36 ug/l; Zn and Mn content of scales of salmon from Lake Bala were 654 and 133 mg/kg respectively; trout scales averaged 532 Zn and 121 Mn. The River Downey had 4 ug Mn/l and 62 ug Zn/l; salmon from the Downey had mean Zn and Mn contents of 1090 and 74 mg/kg, respectively. The upper River Twymyn had highest dissolved Zn levels at 307 ug/l; for Mn this was 11 ug/l; Twymyn trout scales had means of 2075 mg Zn/kg, and 77 mg Mn/kg. Another site at River Twymyn contained Mn levels of 4 ug/l and Zn of 116 ug/l; trout scales from this site contained 844 mg Zn/kg and 39 mg Mn/kg. It is suggested that there is a minimum concentration of zinc in scales at approximately 20-60 mg/kg, above which there is a direct proportion between environmental and scale concentration.

1296. Abdullah, M.I., L.G. Royle and A.W. Morris. 1972. Heavy metals concentration in coastal waters. Nature 235:158-160.

Concentrations of Cu, Pb, Cd and Zn were determined polarographically in water samples collected from a depth of 5 m at Liverpool Bay, Cardigan Bay and Bristol Channel. Very high concentrations of Cd (up to 4.2 ug/l), Pb (up to 5.0 ug/l), zinc (up to 47.6 ug/l) and Cu (up to 4.7 ug/l) found over wide areas appear to be associated with industrial and domestic waste. This may have been caused partly by poor survival of one of the natural agencies of trace metal removal and control, *i.e.* phytoplankton and zooplankton, in heavily polluted waters.

1297. Abraham, M. 1975. The pituitary of *Mugil cephalus* during adaptation to biotopes of different salinities. Aquaculture 5: 199-204.

Epithelial and nervous components of the pituitary of mullet, a euryhaline fish, were analyzed by histological and electron microscope techniques in specimens taken from freshwater ponds, from the sea, and from a hypersaline lagoon. Pronounced differences were found in prolactin secreting cells and neurosecretory axons. Changes in cell structure in different biotopes were also found in somatotrophs, gonadotrophs, corticotrophs and lead-cells of the intermediate lobe. During spawning season, gonadotroph cell region of seawater specimens is characterized by a large number of both A- and B-type neurosecretory axons. It is suggested that Mugil breeders find a method of stimulating synthetic and secretory activity of the gonadotrophs by chlomiphene-like factors as a means towards achieving gonadal activity in freshwater specimens.

1298. Adams, E.S. 1975. Effects of lead and hydrocarbons from snowmobile exhaust on brook trout (Salvelinus fontinalis). Trans. Amer. Fish. Soc. 104:363-373.

Fingerling trout were held in live cages in a Maine pond. This pond contained contaminants accumulated during the previous winter when snowmobile operation on the pond was equivalent to one snowmobile burning 250 liters of fuel per season on a 0.405 h pond (average depth of one m). Lead content of water rose from 4.1 ug/l before snowmobiling to 135 ug/l at ice-out; exposed trout contained 9 to 16 times more lead than controls. Hydrocarbon levels undetectable prior to snowmobiling reached 10 ug/l in water and 1 ug/l in exposed fish. Trout held in aquaria for 3 weeks in melted snow containing different concentrations of snowmobile exhaust showed an increase over controls; those held at the highest concentration (12.5 ug/l Pb in medium) contained 910 ug/kg in fish; controls exhibited 4 ug/l and 640 ug/kg in water and fish, respectively. Digestive tract tissue contained the most lead (2 mg/kg) and gills the least (0.2 mg/kg). Stamina, as measured by the ability to swim against a current, was significantly less in trout exposed to snowmobile exhaust than among control fish.

1299. Adelman, I.R., and L.L. Smith, Jr. 1976. Fathead minnows (Pimephales promelas) and goldfish (Carassius auratus) as standard fish in bioassays and their reaction to potential reference toxicants. Jour. Fish. Res. Bd. Canada 33:209-214.

Minnows and goldfish were compared for suitability as standard bioassay fish. Both species showed the same variability when tested with sodium chloride, pentachlorophenol, Cr^{6+} and Guthion. Minnows were recommended on basis of small size and use in complete life cycle tests. On basis of minimum variability of bioassay results, NaCl was superior for use as a reference toxicant. Pentachlorophenol and NaCl were capable of detecting abnormal fish. For minnows the 24 hr and 96 hr LC-50's were 7910 mg/l and 7650 mg/l for NaCl, and 140 mg/l and 48 mg/l for Cr^{6+}. For goldfish the 24 hr and 96 hr LC-50's were 9952 mg/l and 7341 mg/l for NaCl, and 261 mg/l and 120 mg/l for Cr^{6+}.

1300. Adelman, I.R., L.L. Smith, Jr., and G.D. Siesennop. 1976. Acute toxicity of sodium chloride, pentachlorophenol, Guthion, and hexavalent chromium to fathead minnows (*Pimephales promelas*) and goldfish (*Carassius auratus*) Jour. Fish. Res. Bd. Canada 33:203-208.

LC-50 (96 h) values for NaCl *vs* minnows and goldfish were 7650 and 7341 mg/l, respectively; for hexavalent chromium these were 48 and 120 mg/l. Threshold LC-50's were reached in 6 days for NaCl (7650 mg/l for fathead minnows; 7322 mg/l for goldfish), but were not attained in 11 days with Cr^{6+} (18 and 33 mg/l). With Cr^{6+}, goldfish were more resistant than minnows throughout the 11-day test. With NaCl, goldfish were initially more resistant but at attainment of a threshold LC-50, were less resistant. Use of toxicity curves for assessment of acute mortality permits interpretation not possible in 96 hr tests where LC-50's are computed at 24 hr intervals.

1301. Adema, D.M.M., S.I. De Swaaf-Mooy and P. Bais. 1972. Laboratory investigations concerning the influence of copper on mussels, (*Mytilus edulis*). TNO-nieuws 27:482-487. (In German, English Summary.)

At ambient copper concentrations > 45 ug/l, mussel tissues contained from 50 to 90 mg Cu/kg dry weight after 3 days *vs* 20 mg/kg for controls. All mussels subjected to 45 ug Cu/l died *within* 10 days; greater Cu concentrations produced more rapid mortality. At ambient Cu concentrations of 25 ug/l, 60 mg Cu/kg dry weight was found in mussel tissue within 10 days, and high mortality occurred within 30 days. At 17 ug Cu/l, a Cu content of 80 mg/kg dry weight was reached in 30 days, with only slight mortality. A Cu concentration of 12 ug/l produced no mortality in 30 days although tissue levels rose to 35 mg Cu/kg dry weight. No mortality or elevated tissue Cu levels were produced after exposure for 30 days to 10 ug Cu/l.

1302. Agnedal, P.O. 1966. Calcium and strontium in Swedish waters and fish accumulation of ^{90}Sr. *In* Aberg, B. and F.P. Hungate (eds) Radioecological Concentration Processes. Proc. Inter. Symp. Stockholm, April, 1966. Sym. Pub. Div. Pergamon Press, New York: 879-896.

Various chemical parameters, including Ca, Sr, Mg, Na, and K concentrations in water, are given for 3 Swedish lakes. Average bone concentrations of Ca, in g/kg wet wt, were 45, 36, and 35 for pike, perch, and roach, respectively, with low variations in bone Ca content despite high variations in water. Muscle tissue contained 0.56 (pike), 0.43 (perch), and 0.76 (roach) g Ca/kg. Skin, including scale, concentrations were 33, 73, and 50 g Ca/kg. Respective Sr values for pike, perch, and roach, in mg/kg wet wt, were 51, 53, and 47 in bone; 0.6, 0.7, and 1.3 in muscle; and 50, 108, and 135 in skin and scales. Ratios of Sr:Ca in these fish were 12 to 50% that of water, with Sr substitution most prevalent at low Ca concentrations. Highest Sr:Ca ratios occurred in roach, a mollusc feeder, suggesting intake of Ca and Sr with food. Sr-90 concentrations in fish from Swedish lakes indicates that no hazard to human health is involved if fish are consumed.

1303. Ahokas, R.A. and F.G. Duerr. 1975. Salinity tolerance and extracellular osmoregulation in two species of euryhaline teleosts, *Culaea inconstans* and *Fundulus diaphanus*. Comp. Biochem. Physiol. 52A:445-448.

The LC-50 (96 h) value at 20 ± 1 C for *Culaea inconstans* was 2.1% seawater, and for *Fundulus diaphanus*, 3.4% seawater. With acclimation followed by gradual increase in salinity, the maximum salinity tolerance for *F. diaphanus* was increased to 4.0% seawater. Blood osmolality of both species is maintained relatively constant at salinities tested, predominantly by regulation of blood sodium and chloride. Increased blood glucose and potassium in *F. diaphanus* held in distilled water appears to be a response to stress rather than an osmoregulatory response.

1304. Ahokas, R.A. and F.G. Duerr. 1975. Tissue water and intracellular osmoregulation in two species of euryhaline teleosts, *Culaea inconstans* and *Fundulus diaphanus*. Comp. Biochem. Physiol. 52A:449-454.

Tissue water, chloride space, and intracellular osmotic constituents in muscle of *C. inconstans* and *F. diaphanus* acclimated in distilled water and various salinities of seawater for 96 hr at 20 C were determined. Tissue water increased with increasing salinity in *C. inconstans* (0-17.5°/oo) but remained constant in *F. diaphanus* at all salinities (0-40°/oo). At highest salinities tolerated, chloride space increased in both species, apparently because of shifts in body water from intracellular to extracellular phase. In *C. inconstans*, intracellular Na and Cl levels were low (Na, 156-266 mg/kg cell H_2O; Cl, 105-149 mg/kg) and K was high (4426-4582 mg/kg) but none changed significantly with changing salinity. In *F. diaphanus*, intracellular Na, Cl, and K were lower in 0, 10, and 30°/oo (Na, 100-163 mg/kg; Cl, 82-147 mg/kg; K, 3471-4212 mg/kg) than in 40°/oo (246 mg/kg, 270 mg/kg, and 4446 mg/kg, respectively). Free ninhydrin-positive substances play an active role in intracellular osmoregulation in *F. diaphanus*, but not in *C. inconstans*.

1305. Ahsanullah, M. 1976. Acute toxicity of cadmium and zinc to seven invertebrate species from Western Port, Victoria. Austral. Jour. Marine Freshwater Res. 27:187-196.

Static acute toxicity bioassays were conducted at 34°/oo salinity, 17-20 C, pH 7.8-8.1, with dissolved oxygen at saturation. The most sensitive species to Cd was the amphipod *Allorchestes compressa* with a 120 hr LC-50 of 0.2 mg/l; other species tested were mussel *Mytilus edulis planulatus* with a 96 hr LC-50 of 1.62 mg/l; shrimp *Palaemon* sp. with 120 hr LC-50 of 2.30 mg/l; the polychaete worm *Neanthes vaali* with 168 hr LC-50 of 6.4 mg/l; and crab *Paragrapsus quadridentatus* with a 168 hr LC-50 of 14.0 mg/l. Results of 96 hr static zinc bioassays exhibited the following sensitivities and LC-50's, in mg Zn/l; *A. compressa* 0.58; *M. e. planulatus* 2.5; *Neanthes vaali* 5.5; *Palaemon* sp. 9.5; and *Paragrapsus quadridentatus* 11.0. Results for the echinoderm *Patiriella exigua* and the mollusc *Neotrigonia margaritacea* were inconclusive due to difficulty in determining point of death. Continuous flow bioassays were conducted with *Palaemon* sp., *Paragrapsus quadridentatus* and *M. e. planulatus*, producing LC-50 values that were slightly higher than those in static bioassays.

1306. Ahuja, S.K. 1964. Salinity tolerance of *Gambusia affinis*. Indian Jour. Exp. Biol. 2:9-11.

In culture media containing added NaCl, KCl, $CuCl_2$, $MgSO_4$, Na_2SO_4 and $NaCO_3$ at a total rate of 2 g/l/day, the freshwater fish *G. affinis* showed mortalities of 3 to 5% in 10°/oo salinity, 25 to 30% in 30°/oo salinity and over 95% in salinities of 80°/oo. Saltwater-adapted fish showed decreased activity. Salinity stress was accompanied by sluggish behavior and dorsal surface blood clots.

1307. Akiyama, A. 1970. Acute toxicity of two organic mercury compounds to the teleost, *Oryzias latipes*, in different stages of development. Bull. Jap. Soc. Sci. Fish 36(6): 563-570.

Differential susceptibilities of eggs, developing embryos, fry, and adults of the freshwater fish *O. latipes*, were determined for phenylmercuric acetate (PMA) and methoxyethylmercuric chloride (MEMC). MEMC, an aliphatic organic mercury, was less toxic than PMA, an aromatic organic compound. MEMC LC-50 (24 hr) values for eggs, fry, and adults were 0.50-1.30 mg/l, 1.48 mg/l, and 1.74 mg/l, respectively; for PMA these were 0.18-0.26 mg/l, 0.03 mg/l, and 0.21 mg/l, respectively. LC-50 (24 hr) values for adults using mercuric chloride and copper sulphate (for comparison purposes) were 1.4 mg Hg/l and 40.0 mg Cu/l. Adult fish were more tolerant in all cases than fry. Tolerance increased logarithmically with age; however, eggs in PMA were most resistant.

1308. Alderdice, D.F. and C.R. Forrester. 1971. Effects of salinity and temperature on embryonic development of the petrale sole (Eopsetta jordani). Jour. Fish. Res. Bd. Canada 28:727-744.

Newly-fertilized eggs were incubated at 13 combinations of salinity and temperature between 20 and $35^{o}/oo$, and 4.1 and 8.5 C. Larval length at mean hatching time averaged 2.84 mm for all trials. Percentages of eggs hatching and producing viable larvae were examined with respect to salinities and temperatures of incubation. Calculated optima were: total hatch $29.47^{o}/oo$ S, 6.65 C; viable hatch $27.93^{o}/oo$ S, 7.00 C. At 6.3, 7.2, and 8.1 C, larvae grew to 5.5-5.7 mm total length prior to exhaustion of yolk 246-393 hr after hatching. It was concluded that greatest numbers of viable larvae of largest size at yolk exhaustion would occur from incubation at $27.5\text{-}29.5^{o}/oo$ S and 6-7 C. Laboratory results are related to available hydrographic and meteorological data for a spawning area off the west coast of Vancouver Island. Estimates are given of direction, depth, and duration of drift of the pelagic stages until yolk exhaustion. Environmental variability in spawning period is related to existing measures of year-class strength. Effect of temperature on egg development is related to range of species in terms of estimated temperatures available at spawning depths.

1309. Alexander, G.V. and D.R. Young. 1976. Trace metals in southern Californian mussels. Marine Poll. Bull 7(1):7-9.

Ranges of metals in mg/kg dry wt in Mytilus californianus digestive glands were: 2 to 38 for Pb; 14 to 69 for Cu; 2 to 61 for Cr; 0.7 to 33 for Ag; 46 to 110 for Zn; and 3 to 20 for Ni. Authors suggest that Pb distribution was dominated by diffuse inputs, while Cu, Cr, and Ag were related to urban point sources. No pattern for Ni or Zn was observed.

1310. Alexander, J.E., J. Foehrenbach, S. Fisher and D. Sullivan. 1973. Mercury in striped bass and bluefish. New York Fish Game Jour. 20:147-151.

In bluefish from Montauk Point, Long Island, Hg levels in mg/kg wet wt were: < 0.5 for fish weighing < 2.4 kg; ~ 0.5 for 2.4 to 5.6 kg individuals; and > 0.5 for fish weighing > 5.6 kg. Corresponding weight categories for striped bass were: < 3.2 kg, 3.2 to 5.7 kg, and > 5.7 kg, respectively.

1311. Allee, W.C. and E.S. Bowen. 1932. Studies in animal aggregations: mass protection against colloidal silver among goldfishes. Jour. Exp. Zool. 61(2):185-207.

A group of 10 goldfish survived longer than isolated goldfish in similar volumes and concentrations of colloidal Ag. When exposed to the same volume of colloidal Ag per individual, grouped and isolated fishes showed similar susceptibility. In a processionary series of fishes in the same suspension of colloidal silver, later individuals survived longer. Grouped fishes removed more colloidal Ag from suspension than isolated fishes; this alone could account for greater group survival. Suspensions of colloidal Ag in which fishes died, or lived up to 24 hrs contained less unadsorbed Ag than controls, even when double the amount is added. CO_2 did not protect the group from colloidal Ag. Urinary excretions, feces, and slime secretions protect fish from colloidal Ag; depressed metabolism was not an important protective mechanism.

1312. Allee, W.C. and J.F. Schuett. 1927. Studies in animal aggregations: the relation between mass of animals and resistance to colloidal silver. Biol. Bull. 53:301-317.

Using annelid worms, crustaceans, platyhelminthes, coelenterates, echinoderms, higher plants and molluscs, it was shown that there is greater protection with increasing biomass on exposure to equal amounts of colloidal silver and water. Protection is due to fixation of toxic substance by the mass of animals with each receiving a sub-lethal dose; isolated individuals in same concentration receive a stronger dose. Colloidal Ag may be differently fixed in different animals but in slime-secreting animals like planarians it is absorbed on the slime. Protection furnished by mass is independent of species. Authors suggest that other inert substances capable of fixing colloidal Ag by absorption should produce the same effect.

1313. Allen, K. 1961. The effect of salinity on the amino acid concentration in Rangia cuneata (Pelecypoda). Biol. Bull. 121(3):419-424.

Concentration of 4 amino acids increased in clams with increasing salinities from $3^{o}/oo$ to $17^{o}/oo$. Further salinity increases to $25^{o}/oo$ resulted in decreased amino acid content/gm tissue dry wt. An abundance pattern of alanine > glycine > glutamic acid > aspartic acid did not change throughout the study. Increased environmental salinities resulted in water loss from tissues.

1314. Amiard, J.-C. 1975. Interpretation d'une etude experimentale du metabolisme du radiostrontium chez la plie (Pleuronectes platessa) a l'aide des analyses factorielles. Rev. Intern. Oceanogr. Med. 39-40:177-212.

Several studies were conducted on Sr metabolism in flatfish P. platessa, as influenced by various biotic and abiotic factors. Using Sr-85, strontium uptake occurred mainly in soft tissues during the earliest contamination stage; after the 12th day it occurred mainly in hard tissues. Colder temperature, the passage from brackish to seawater, and from gravel to sand, were all associated with lowered strontium uptake. Within experimental limits Ca concentration had no effect on Sr uptake.

1315. Amiard. J.-C. 1976. Phototactic variations in crustacean larvae due to diverse metallic pollutants: demonstrated by a sublethal toxicity test. Marine Biology 34:239-245. (In French, English summary.)

Orientation of crab zoae (C. maenas) to light during 96 hr period was disrupted by 0.01 to 0.1 mg $CoCl_2$/l, 0.01 to 0.1 mg $AgNO_3$/l, or 100 mg $SrCl_2$/l. For shrimp zoae Palaemon serratus, corresponding values in mg/l, were 100 to 500 for $CoCl_2$, 100 for $AgNO_3$ and 500 for $SrCl_2$. C. maenas photokinesis was decreased by amounts of 0.001 mg/l of $CoCl_2$ or $AgNO_3$ within a period of 2 to 3 days.

1316. Amiard, J.-C., J.C. Harduin and G. Odilon. 1976. Etude de l'influence d'une surcharge en chlorure de cobalt sur la composition en acides amines libres de l'hemolymphe du crustace decapode: Carcinus maenas L. Cahirs Biol. Marine. 17:295-303.

Crabs exposed to 10 mg/l of cobalt chloride for 8 days at 15 C, exhibited changes in haemolymph amino acid composition. When compared to controls, cobalt-exposed crabs showed increases in 10 "non-essential" amino acids (cyteic, aspartic and glutamic acids, glycine, alanine, l-methylhistidine, arginine and ASN+glutamine) and decreases in concentrations of 3 "essential" amino acids (methionine, lysine and histidine).

1317. Amiard-Triquet, C. and J.-C. Amiard. 1975. Etude experimentale du transfert du cobalt 60 dans une chaine trophique marine benthique. Helgol. wiss. Meeresunters 27:283-297.

Experiments were conducted to quantify transfer of Co-60 from the environment to various components of a benthic food chain. The food chain tested comprised diatom *Navicula* sp., bivalve *Scrobicularia plana*, shore crab *Carcinus maenas*, and rat *Rattus rattus*. Diatoms take up large quantities of radiocobalt. The radioactivity accumulated (per unit weight) by organisms studied decreases from one trophic level to the next: from about 3200 nCi/g in *Navicula* at equilibrium to 40 in *Scrobicularia* at equilibrium to 12 in *Carcinus* to 0.03 in rats. There is some biological control in Co-60 uptake by these species. For all species except *Navicula* the quantity of Co-60 assimilated is independent of quantity ingested with food. Preferential sites of cobalt accumulation are liver and kidneys in rat, and hepatopancreas in the two invertebrate species examined.

1318. Amiard-Triquet, C. and J.-C. Amiard. 1976. L'organotropisme du ^{60}Co chez *Scrobicularia plana* et *Carcinus maenas* en fonction du vecteur de contamination. Oikos 27:122-126. (In French, English summary.)

In the bivalve mollusc *S. plana*, and crab *C. maenas*, the surrounding water is the primary source of external Co-60 contamination; internal contamination results largely from food intake. In both species Co-60 is accumulated in large quantities by digestive gland. Edible parts of *S. plana* are contaminated with Co-60, whereas digestive gland of *C. maenas* is not generally eaten.

1319. Amiel, A.J., G.M. Friedman and D.S. Miller. 1973. Distribution and nature of incorporation of trace elements in modern aragonitic corals. Sedimentology 20:47-64.

Experiments based on dissolution rate of aragonite in distilled water and the substitution of Sr and Mg by Ca and Na have shown that the main site for Sr in corals is in the aragonite lattice. For Mg, 25% of the total occurs in adsorbed sites and organic compounds. The remaining Mg may be located in the aragonite lattice, but is easily removed by leaching or replacement with Ca. About 12% of total Na is in adsorbed sites and included in organic compounds; remaining Na may be in lattice replacing Ca. K is in adsorbed sites and incorporated in organic compounds to a higher degree than other elements examined (30% of total K). After 5 months in the substitution experiment, calcite replaced aragonite on coral surfaces after inhibitor Mg was exchanged from surface sites and replaced by Ca. Organic compounds of corals contain about 500 mg/kg Sr, 190-325 mg/kg Mg, 600-620 mg/kg Na and < 100 mg/kg K.

1320. Ancellin, J., P. Bovard, and A. Vilquin. 1967. New studies on experimental contamination of marine species by ruthenium-106. Actes du Congres Int. sur la radioprotection du milieu Soc. Franc. de radioprot. Toulouse, France, 14-16 Jan. 1967: 213-234. (In French.)

Laboratory uptake studies of Ru-106 from medium by various species of marine alga, coelenterates, molluscs, crustaceans, ascidians, and teleosts were conducted. In 200-250 hours, concentration factors ranged from 100 to 200 for algae, 20 to 50 for invertebrates, and about 1 for fish. The algae *Corallina officinalis* and the ascidian *Dendrodoa grossularia* were the most active concentrators.

1321. Anderlini, V. 1974. The distribution of heavy metals in the red abalone, *Haliotis rufescens* on the California coast. Arch. Environ. Contamin. Toxicol. 2(3):253-265.

Ranges of mean metal levels in mg/kg dry wt of gills of abalones (mollusc) from 5 localities were 13 to 129 for Ag, 4 to 20 for Cd, 0.6 to 4.0 Cr, 19 to 124 Cu, always <0.1 for Pb, 0.08 to 0.27 Hg, 69 to 112 Ni, and 28 to 54 Zn. Mantle values were 16 to 54 for Ag, 3 to 13 Cd, 0.0 to 13 Cr, 9 to 20 Cu, always <0.1 for Pb, 0.02 to 0.33 Hg, 19 to 57 Ni, and 42 to 74 for Zn. Digestive glands contained 14 to 60 Ag, 184 to 1163 Cd, 2 to 13 Cr, 11 to 78 Cu, 9 to 41 Pb, 0.12 to 4.64 Hg, 3 to 11 Ni, and 536 to 980 for Zn. Foot tissue levels in mg/kg dry wt, were 1 to 44 for Ag, 0.2 to 0.5 for Cd, below detection levels for Cr, 1 to 13 for Cu, <0.1 for Pb, 0.03 to 0.09 for Hg, 0.2 to 1.6 for Ni and 38 to 46 for Zn. Metal concentrations were not correlated with size of organism; however Cu and Ag concentrations were inversely correlated, with Cu decreasing and Ag increasing from north to south. High Hg concentrations in La Jolla-Long Beach area reflect pollutant inputs; elsewhere,Hg levels appeared to derive from natural sources.

1322. Andersen, A.T., A. Dommasnes and I.H. Hesthagen. 1973. Some heavy metals in sprat (*Sprattus sprattus*) and herring (*Clupea harengus*) from the inner Oslofjord. Aquaculture 2:17-22.

Respective mean metal levels, in mg/kg dry wt of sprat, and herring, were 5.6 and 4.4 for Cu, 133 and 119 for Zn, 0.3 and <0.2 for Cd and 8.2 and 7.0 for Pb.

1323. Andryushchenko, V.V. and G.G. Polikarpov. 1974. An experimental study of uptake of Zn^{65} and DDT by *Ulva rigida* from seawater polluted with both agents. Hydrobiol. Jour. 10(4): 41-46.

Uptake of Zn-65 by algae Ulva rigida was reduced 12 to 36% over controls by 1 mg DDT/l.

1324. Annett, C.S., F.M. D'Itri, J.R. Ford, and H.H. Prince. 1975. Mercury in fish and waterfowl from Ball Lake, Ontario. Jour. Environ. Qual. 4:219-222.

A total of 323 fish samples representing 8 species, and 26 waterfowl samples of 3 species were collected from the Ball Lake area of the Wabigoon-English River systems in NW Ontario and analyzed for total mercury by flameless atomic absorption. The average total Hg concentrations of walleye and pike (teleosts) were 3.24 and 5.55 mg/kg wet wt, respectively. The highest total Hg concentrations in fish during the entire study were 19.71 and 16.09 mg/kg wet wt, respectively, in muscle tissue of a walleye and a pike. Frequency distributions of total Hg levels in fish are presented by species and sampling location. The highest average Hg levels in breast muscle and liver tissue of three species of waterfowl were 8.3 (breast)and 98.5 (liver) mg/kg wet wt.

1325. Annett, C.S., M.P. Fadow, F.M. D'Itri, and M.E. Stephenson. 1972. Mercury pollution and Lake Erie fishes. The Michigan Academician 4(3):325-337.

To assess extent of mercury contamination of Lake Erie in the vicinity of the Raison River, 79 fish and 37 sediment samples were analyzed. The average Hg content in mg/kg dry wt in fish species were 0.49 in perch Perca flavescens, 0.28 in goldfish Carassius auratus, 0.19 in carp Cyprinus carpio, 1.7 in sheepshead Alpodinotus grunniens, 0.4 in pumpkinseed Lepomis gibbosus, 0.18 in carpsucker Carpiodes, and 0.67 in a carp-goldfish hybrid. Total Hg concentrations of surface water samples were nearly always <0.1 ug/l; levels in sediments were evenly distributed with a range of 0.19 to 0.53 mg/kg dry wt. No correlation was evident between size of fish and total Hg content within a given species. A trend in Hg accumulation was observed among species, with mean total Hg levels having a declining order in perch, goldfish and carp.

1326. Anon. 1915 (1916). Dept. of Biology, N.J. State Agric. Exper. Station, 1915, Annual Report. Trenton, N.J., Section 5: 246-249.

Numerous conjectures are made concerning the green color of oysters. The primary hypothesis proposed here is that green color is related to a deficiency of oxygen in water, producing an increase or compositional change in respiratory pigment of these oysters. It is suspected that uncolored oysters always have this substance present and with suitable culturing techniques oysters could be produced in any desirable hue. Blue oysters contained approximately 26.7 mg Cu/g dry wt compared to approximately 8.4 mg/g for white oysters.

1327. Anon. 1972. Mercury pollution investigation in Georgia 1970-1971. Georgia Water Quality Control Board, 47 Trinity Ave., Atlanta, Ga.: 117 pp.

In 7 major freshwater river basins exclusive of the Savannah River, average mercury contents in mg/kg wet wt were 0.38 for largemouth bass and 0.20 for catfish. In the Savannah River from Augusta to Savannah, largemouth bass and American shad contained 1.5 and 0.23 mg Hg/kg, respectively. In the Savannah Estuary, shrimp, blue crabs, flounders and eastern oysters had average Hg contents of <0.5 mg/kg. Blue crabs from the Georgia coast exclusive of the Brunswick area contained 0.14 mg Hg/kg. In the Brunswick area, Hg content of blue crabs decreased from 1.09 to 0.56 mg/kg during the study interval. The Savannah River from Augusta to Savannah and the Brunswick area were characterized by biotic Hg levels greater than 0.5 mg/kg (the current Food and Drug Administration Hg limit for food). Both regions received discharges from mercury-cell-type chlor-alkali plants.

1328. Anon. 1974. Progress and projections, Fisheries and marine service, Vancouver laboratory, 6640 N.W. Marine Drive, Vancouver, B.C.: 21 pp.

Inclusion of 8% herring meals (containing 0.17 to 0.22 mg/kg mercury) in diet of laying birds (chickens) had no effect on mortality, fertility, hatchability, or rate of lay and egg quality; Hg did not accumulate in meat or eggs.

Another study reports on effects of Cd and Cu salts on lactic acid oxidation from gills of exposed fish. However, this test had value only at high exposure levels (1.1 mg/l Cd or 0.06 mg/l Cu).

A third study documented stress response of salmon to low levels of copper. Yearling sockeye salmon exposed to low concentrations of Cu for 1 to 24 hr, exhibited abnormal plasma cortisol and cortisone concentrations. The highest concentration tested of 0.635 mg/l Cu caused sharp increase in cortisol concentration in 1 hr and was fatal in 8 to 24 hrs; 0.0635 mg/l Cu produced stress but no deaths in 24 hrs; 0.00635 mg/l produced slight effect which was not measurable after 4 hrs.

1329. Anon. 1975. Great Lakes environmental contaminants survey 1973. Avail. from Int. Joint Comm. Great Lakes Reg. Off., 100 Ouellette Ave., Windsor, Ontario, Canada.

Residues of DDT's, PCB's, dieldrin, and mercury in flesh of Great Lakes fishes were determined by several resource agencies. Highest mercury values recorded in Lake Huron teleosts in mg/kg wet wt, were 0.55 ± 0.36 for walleyes, and 0.60 ± 0.12 for catfish. For Lake Erie teleosts highest individual Hg values were 0.56 ± 0.16 for walleye, 0.55 for yellow perch, 0.54 for white bass, 0.48 ± 0.26 for drum, and 0.34 ± 0.19 for carp. For Lake Michigan, highest Hg values were noted in selected lake trout (0.57), and salmon (0.55). One lake trout in Superior contained 0.80 ± 0.30 mg Hg/kg wet wt, but all other samples and species therein contained <0.20. Mercury levels were comparatively high in Lake St. Clair walleyes (1.11 ± 0.46), yellow perch (0.52) and white bass (0.35).

1330. Antia, N.J. and J.Y. Cheng. 1975. Culture studies on the effects from borate pollution on the growth of marine phytoplankters. Jour. Fish. Res. Bd. Canada 32:2487-2494.

Growth rates of 19 species of marine algae were unaffected by incorporation of 5 to 10 mg B/l into a nutrient-enriched, pH-controlled seawater medium. However 26% of the species were strongly inhibited by 50 mg of B/l and this proportion increased to 63% at 100 mg of B/l. Several species required prolonged periods of adaptation before exponential growth with 50 to 100 mg of B/l. Both adaptation period and degree of inhibition were gradually mitigated on sequential transfer of certain species from lower to higher B concentration. This suggested that the majority of species inhibited initially could maintain good growth at 50 mg but not 100 mg B/l (a concentration lethal to 37% of species).

1331. Antonini-Kane, J., S.W. Fowler, M. Heyraud, S. Keckes, L.F. Small and A. Veglia. 1972. Accumulation and loss of selected radionuclides by Meganyctiphanes norvegica M. Sars. Rapp. Comm. Int. Mer Medit. 21(6):289-290.

Concentration ratios, defined as activity per mg live wt divided by activity per ml water, for euphausiids after exposure for 12 hrs were: 85 for Zn-65, 65 for Ce-141, 30 for Fe-59, 20 for Ru-106 (Cl form) and 3 for Ru-106 (N form). After 12 hrs in isotope-free medium, 10% of Ce-141, 25% of Zn-65, 30% of Fe-59 and 35% of Ru-106 was lost. Molting reduced isotope contents of animals drastically, provided that initial uptake was directly from medium. When uptake vector was food chain, molting loss was insignificant.

1332. Argiero, L., S. Manfredini and G. Palmas. 1966. Absorption de produits de fission par des organismes marins. Health Physics 12:1259-1265. (In French, English summary.)

Accumulation of Sr-90 and Cs-137 by mussel, *Mytilus galloprovincialis*, from seawater was determined. With Sr-90, equilibrium is maintained after 120 hrs with concentration factor of 3.6 (fresh wt) and 98.3 (ash wt). For Cs-137, equilibrium is reached in about 100 hrs. The Cs-137 c.f. varied from 4.3 for adults to 6.4 for juveniles (fresh wt basis); on an ash wt basis c.f. ranged from 117 for adults to 175 for juveniles.

1333. Arima, S. and S. Umemoto. 1976. Mercury in aquatic organisms — II Mercury distribution in muscles of tunas and swordfish. Bull. Jap. Soc. Sci. Fish. 42(8):931-937. (In Japanese, English summary.)

Total mercury concentrations ranged from 0.74 to 2.34 mg/kg in muscle of bigeye tuna *Thunnus obesus*, bluefin tuna *T. thunnus*, and swordfish *Xiphias gladius*. Myofibrillar proteins contained 57 to 68% of total muscle Hg; combined myofibrillar and sarcoplasmic protein fractions contained 71 to 89% of total muscle Hg. At low Hg residues levels, Hg was preferentially incorporated into myofibrillar proteins. At higher levels, both myofibrillar and sarcoplasmic proteins incorporated Hg.

1334. Armstrong, F.A.J. and A.L. Hamilton. 1973. Pathways of mercury in a polluted Northwestern Ontario lake. *In*: Singer, P.C. (ed). Trace metals and metal organic interactions in natural waters. Ann Arbor Sci. Publ., Ann Arbor, Mich.: 131-156.

The Wabigoon River-Clay Lake-English River-Winnipeg River system in western Ontario and eastern Manitoba was studied because of its high mercury content. The source of the contamination was a chlorine-alkali plant which during 8 years of unregulated operation, 1962-1969, may have discharged 9,000 to 11,000 kg Hg. Elevated Hg concentrations were found in top 5-6 cm of sediments. Biological sampling showed that organisms living in bottom sediments or attached to littoral vegetation had much higher concentrations than organisms living or feeding in water column. Zooplankton always contained <0.1 mg Hg/kg wet wt, while mayfly and midge larvae from bottom sediments contained 0.1 to 1.0 mg Hg/kg wet wt. Hg was related to food selection for omnivores, organisms feeding on detritus, or bottom-dwelling invertebrates such as annelids, molluscs and crustaceans. These had much higher Hg levels than herbivores or organisms feeding on zooplankton. It appears that Hg uptake via food chain is more significant than direct uptake from water or sediment. A survey of Hg concentrations in crayfish *Orconectes virilis* showed that Hg accumulates unevenly throughout body with highest levels in abdominal muscle. Most of the Hg concentrated by crayfish is in methylated form, with a definite age-mercury concentration relationship. Hg levels in crayfish decreased as a reflection of improving conditions; the use of *Orconectes* as an indicator of Hg pollution is proposed.

1335. Aronson, J.L., M. Spiesman and A.K. Aronson. 1976. Note on the distribution of mercury in fish species in three Ohio lakes. Environ. Pollut. 10:1-7.

Sunfish *Lepomis macrochirus* and *L. gibbosus*, yellow perch *Perca flavescens*, channel catfish *Ictalurus punctatus*, bullhead *I. nebulosis*, and white bass *Morone chrysops* from two large non-industrialized lakes in Ohio contained about 0.1 mg Hg/kg. Carp *Cyprinus carpio*, contained 0.25 mg Hg/kg. At Fairport Harbor, Lake Erie, all species contained 0.25 to 0.35 mg Hg/kg. Authors suggest that ubiquitous carp, rather than fish higher in food web, may be best biological magnifiers for inter-lake comparisons of Hg in unpolluted, moderately eutrophic lakes.

1336. Avio, C.M. and L. Lenzerini. 1963. Captazione del Cs^{137} da parte di *Chlorella vulgaris*. Pubbl. Staz. Zool. Napoli 33:69-82. (In Italian, English summary.)

Growth of the alga *Chlorella* was not affected by 0.9 ug of Cs/1, but was inhibited by 100 ug Cs/1. Cs-137 was accumulated in a linear fashion with a concentration factor of 0.0011 for 10^6 cells. Cesium uptake was a direct function of cell number and Cs concentration in medium.

1337. Bache, C.A., W.H. Gutenmann, and D.J. Lisk. 1971. Residues of total mercury and methylmercuric salts in lake trout as a function of age. Science 172:951-952.

Whole yearling trout *Salvelinus namaycush*, from Cayuga Lake, N.Y. contained 0.19 to 0.28 mg Hg/kg wet wt; methyl-Hg constituted 3.0 to 35.0% of the total Hg. Total Hg and proportion of Me-Hg to total Hg showed increases with age; 12 year old trout contained 0.44 to 0.62 mg Hg/kg wet wt of which 66.9 to 88.4% was Me-Hg.

1338. Bachenheimer, A.G. and E.O. Bennett. 1961. The sensitivity of mixed populations of bacteria to inhibitors I. the mechanism by which Desulfovibrio desulfuricans protects Ps. aeruginosa from the toxicity of mercurials. Antonie van Leeuwenhoek Jour. Microbiol. Serol. 27:180-188.

Concentration of phenylmercuric lactate required to completely prevent growth of Pseudomonas aeruginosa increased from 200 in pure culture to 900 mg/l when D. desulfuricans was introduced. Similar results obtained from hydrogen sulfide leads to the conclusion that hydrogen sulfide produced by sulfate-reducers protects both organisms from mercurial inhibition.

1339. Bachmann, R.W. and E.P. Odum. 1960. Uptake of Zn^{65} and primary productivity in marine benthic algae. Limnol. Oceanogr. 5(4):349-355.

Uptake of Zn-65 by six species of algae occurred in the light, but not in the dark. Initial rate of uptake in light was proportional to gross oxygen production which varied with species. Apparent equilibrium uptake rates in Chaetomorpha at different light intensities were proportional to net oxygen production. In marine seaweeds, Zn is taken up and accumulated in proportion to gross oxygen production; consequently, Zn-65 has possibilities as a tool for measurement of primary productivity.

1340. Backstrom, J. 1969. Distribution studies of mercuric pesticides in quail and some fresh-water fishes. Acta Pharmacol. Toxicol. 27(Supp. 3):3-103.

Using Japanese quail and several species of freshwater fish the localization of Hg was followed after parenteral or peroral administration of methyl mercury, phenyl mercury, methoxyethyl mercury, and inorganic mercury (Hg^{2+}); mercurials were labelled with Hg-203. In some avian experiments the stability of the carbon-mercury bond in methyl and phenyl mercury was examined by comparative studies of compounds double-labelled with Hg-203 and C-14. Administration route was of minor importance for the final qualitative distribution of mercury; methyl mercury was readily absorbed after ingestion while the other compounds were less well absorbed. The methyl mercury radical was comparatively stable in the avian body, but phenyl mercury was rapidly decomposed to inorganic mercury. Distribution of methyl mercury in quail differed from other mercurials, the latter presenting great similarities with each other. Methyl mercury was characterized by an even distribution of mercury in most organs including kidneys, and by a slow excretion. After injection of methyl mercury, brain slowly reached a high concentration of Hg. Injection of other mercurials resulted in negligible cerebral uptake of Hg. An increased dosage of phenyl, methoxyethyl and inorganic mercurials resulted in more Hg being excreted via the eggs. With the methyl mercurial a higher dose increased excretion only slightly. Plumage and other keratinized structures strongly concentrated Hg for all Hg compounds given, and this seems to be an important route of excretion of mercurials, especially methyl mercury. A pronounced concentration and retention of Hg was observed in avian anterior pituitary with phenyl, methoxyethyl and inorganic mercurials. Depending on type of mercurial, accumulations of Hg were observed in adrenal medullary cells, in pancreas, in certain nuclear areas in brain, in ganglia, in germinal discs and in epididymis. With phenyl and methoxyethyl mercurials the Hg-ratio between blood corpuscles and blood plasma was similar to that of the methyl mercurial, but after longer survival times it was more similar to the inorganic mercurial. This finding is consistent with a decomposition of the two organo-mercurials to inorganic mercury. Electrophoresis, combined with autoradiography and isotope scanning of the avian blood proteins demonstrated marked sex differences in the localization of mercury. Electrophoresis was also run with yolk and egg white samples from Hg-contaminated eggs, which resulted in characteristic localizations of Hg depending on type of mercurial.

In the piscine experiments, the most outstanding feature was the slow kinetics of mercury once distributed. No great differences in distribution of mercury were observed between species. Differences between various compounds were less prominent than in the avian experiments. The principal distribution otherwise showed many similarities with corresponding patterns in birds. However, thyroid and spleen demonstrated a much higher uptake of mercury in fishes than in birds. Injection of phenyl mercury into fishes also resulted in a strong retention of mercury in the wall of gall bladder and in cortical layer of myocardium. These localizations of mercury were not observed in birds. After injection of methyl mercury there was a steadily increasing uptake of mercury in fish muscle and brain throughout the study. Injection of the inorganic mercurial resulted in a similar increasing uptake in kidney, spleen, and liver. A pronounced difference was observed between white and red flesh, the latter accumulating considerable more Hg than the former. Phenyl mercury strongly accumulated in piscine liver, which may be related to a green color presumably caused by bile pigments, which appeared in flesh of pikes kept in water containing phenyl mercury. A high uptake of mercury was noted in gills and pseudobranch. The significance of these localizations is uncertain, but damage to these organs in fishes poisoned by mercurials have been reported.

1341. Baker, P.F., H. Meves and E.B. Ridgway. 1973. Effects of manganese and other agents on the calcium uptake that follows depolarization of squid axons. Jour. Physiol. 231:511-526.

Tetrodotoxin-insensitive components were blocked, reversibly, by concentrations of Mn, Co and Ni that reduced but did not block tetrodotoxin-sensitive component. Late component was also blocked by La^{3+} and organic Ca antagonists D-600 and iproveratril. Mn^{2+}, Co^{2+}, and Ni^{2+} and the drug D-600 all reduced Na currents, but had little effect on either outward or inward K currents. Tetraethyl-ammonium blocked outward K current but had no appreciable effect on tetrodotoxin-insensitive entry of Ca. Concentrations of Mn between 0.28 and 2.8 g/l substantially reduced light output during a train of action potentials and slightly reduced rate of action potential rise. It was concluded that a tetrodotoxin-insensitive component of Ca entry does not represent Ca ions passing through K permeability channels. There must exist a potential-dependent late Ca channel distinct from Na and K channels of the action potential.

1342. Baker, P.F., H. Meves and E.B. Ridgway. 1973. Calcium entry in response to maintained depolarization of squid axons. Jour. Physiol. 231:527-548.

External K concentrations >2.0 g/l produced a phasic light response. Light rose to a peak in a few seconds and then fell in 0.5 to 5 min to a new steady level that was greater than level in absence of K. Phasic light response seems to reflect a phasic entry of Ca in response to depolarization. Similar phasic responses were produced by prolonged electrical depolarization. Results were consistent with depolarization serving both to activate and also to inactivate Ca entry. Following inactivation and return to normal seawater, there was an appreciable relative refractory period during which the response both to K-rich seawater and electrical depolarization was reduced in size; complete recovery took 10-15 min. Pre-treatment with 7.4 or 14.8 g KCl/l reduced response to 30.3 g KCl/l. Phasic Ca entry produced by K-rich solutions was insensitive to external tetrodotoxin and internal tetraethylammonium ions, but was blocked by external Mn^{2+}, Co^{2+} and Ni^{2+} ions and by D-600 and iproveratril, suggesting that phasic Ca entry involves the late Ca channel. Outward K current recovery after a long depolarization was faster than recovery of late Ca entry system, providing support for view of distinct K and late Ca channels.

1343. Bakunov, N.A. 1975. The biological test organism in marine radioecological investigations. Soviet Jour. Ecol. 5:67-70.

Cesium-137 content in six species of fishes from the Caspian Sea was determined. Herring _Clupeonella engrauliformis_ contained 53 to 97 pCi/kg wet wt, or less variation in this parameter than other fish species examined; mean radioactivity values were intermediate. Because _C. engrauliformis_ is planktiverous and abundant over a wide range, it is recommended as an appropriate indicator of radionuclide pollution.

1344. Ball, E.G. and B. Meyerhof. 1940. On the occurrence of iron-porphyrin compounds and succinic dehydrogenase in marine organisms possessing the copper blood pigment hemocyanin. Jour. Biol. Chem. 134:483-493.

Iron-porphyrin compounds were found in tissues of horseshoe crab Limulus polyphemus, whelk Busycon canaliculatum, lobster Homarus americanus, and squid Loligo pealii; hemocyanin is the blood pigment in these species. Myoglobin was present in high concentration in radula muscles of Busycon. Authors concluded that oxygen utilization in these organisms is similar to that in mammals except for substitution of hemocyanin for hemoglobin. Substitution can not be ascribed to inability to utilize Fe or to synthesize porphyrin group characteristic of Fe respiratory pigments. Two additional hemochromogens occurred in Limulus. One in the clot obtained from blood, the other in eggs. A hemin was also found in eggs of sea urchin, Arbacia punctulata.

1345. Banus, M., I. Valiela, and J.M. Teal. 1974. Export of lead from salt marshes. Marine Poll. Bull. 5:6-9.

Lead accumulates in shallow salt marsh sediments with subsequent uptake by grasses including Spartina alterniflora. Since about half the annual grass crop is transported to the sea after the grass dies, this may contribute to movement of Pb to deeper waters. Where nitrogen additions increase biomass of grasses, or where heavy Pb contamination takes place, substantial amounts of Pb may be removed by tides from marsh surfaces. A model was constructed in which authors estimated Pb inputs from atmosphere into marsh at about 12 mg Pb/m^2; this is reflected as 730 mg Pb/m^2 in sediments, 28 in grasses, and 14 mg Pb/m^2 losses to the sea. Higher values were calculated for fertilized plots with ultimate losses to the sea at 58 mg Pb/m^2.

1346. Bargmann, G.G. and G.W. Brown, Jr. 1973. Fish muscle alpha-glycerophosphate dehydrogenase and its inhibition by metals. In: Research in Fisheries Annual Rept. Coll. Fisheries, Univ. of Wash., Seattle, Wash.: 56.

Activity of alpha-glycerophospate dehydrogenase of rainbow trout Salmo gairdneri muscle was reduced to 50% of control value by addition, in mg metal/kg wet wt muscle, of 0.2 Hg^{2+}, 1.1 Cd^{2+}, 3.3 Zn^{2+}, 6.4 Cu^{2+}, 83 Pb^{2+}, or 120 Ni^{2+}.

1347. Barnard, H.E. 1911. Some poisons found in food. Pure Products 7:145-148.

Arsenic values, in ug/kg were 27 to 39 in mackerel and 1 to 76 in shrimp. In lobsters, As contents, in ug/kg, were 22 in muscle tissue, 357 in eggs and fat, 1040 in flesh, and 453 in the whole body. Oysters contained 40 to 447 mg copper/kg fresh weight.

1348. Barnes H. and F.A. Stanbury. 1948. The toxic action of copper and mercury salts both separately and when mixed on the harpacticid copepod, Nitocra spinipes (Boeck). Jour. Exp. Biol. 25:270-275.

At a concentration of 0.6 mg Hg/l and no Cu, 50% of N. spinipes died after 24 hrs. Copper alone at 0.026 mg Cu/l killed 1.3%, but when added to 0.6 mg Hg/l the mixture killed 62%. Different concentrations of Cu and Hg showed similar synergistic effects when mixed, and suggest that the two toxicants act in a different manner.

1349. Bartlett, L., F.W. Rabe and W.H. Funk. 1974. Effects of copper, zinc and cadmium on Selanastrum capricornutum. Water Research 8:179-185.

Algicidal and algistatic effects of copper, zinc and cadmium on the freshwater green algae S. capricornutum were determined. Algicidal concentrations of Cu, Zn and Cd were 0.30, 0.70 and 0.65 mg/l, respectively. Initial growth rate inhibition occurred for Cu, Zn and Cd at concentrations of 0.05, 0.03, and 0.05 mg/l, respectively. A 5/1, 5/2 and 5/3 ratio of Zn/Cu (0.5 mg Zn/l + 0.1, 0.2 and 0.3 mg Cu/l) produced growth rates similar to 0.6, 0.7, and 0.8 mg Zn/l; the same combinations of Zn and Cd also resulted in rates similar to Zn. Combinations of Cu and Cd produce greater growth than an equal concentration of Cu suggesting that Cd inhibits toxicity of Cu.

Selanastrum could exist in water from the upper South Fork and North Fork of the Coeur d'Alene River, where Zn and other metals were in low concentrations. This species was unable to tolerate Zn concentrations greater than 0.5 mg/l from other parts of the drainage, and this is consistent with laboratory findings.

1350. Baudouin, M.F. and P. Scoppa. 1974. Acute toxicity of various metals to freshwater zooplankton. Bull. Environ. Contamin. Toxicol. 12:745-751.

Cyclops abyssorum, Eudiaptomus padanus, and Daphnia hyalina were used to determine the toxicity of various metal salts. For Daphnia, the most sensitive of the three, the 48-hr LC-50's, expressed in mg/l were 3000 for Ca, 75 for Sr, 32 for Mg, 7.4 for Cs, 1.9 for Ni, 1.32 for Co, 0.60 for Pb, 0.055 for Cd, 0.05 for Cu, 0.04 for Zn, 0.022 for Cr^{+6}, and 0.0055 for Hg.

1351. Beadle, L.C. 1931. The effect of salinity changes on the water content and respiration of marine invertebrates. Jour. Exp. Biol. 8(3):211-227.

On transference to low salinity medium, both body weight and respiration rate of Nereis diversicolor, a polychaete, at first increased and then fell. With N. cultrifera, weight increased but did not subsequently fall; respiratory rate also increased, but less than that of N. diversicolor. Differences in respiratory rate were greater in 16.6% seawater than in 25% SW. N. diversicolor maintained activity but N. cultrifera became inert in dilute water and died after exposure for 50 hrs to 16.6% SW.

Respiratory rate of Gunda ulvae, a marine flatworm, increased proportionally to initial osmotic gradient between animal and environment. Swelling of Gunda was due to vacuolation of gut cells; other tissues appeared unaltered. Osmotic resistance mechanisms in N. diversicolor and G. ulvae are different.

1352. Beal, A.R. 1974. A study of selenium levels in freshwater fishes of Canada's Central Region. Canada Dept. Environment Fish. Marine Serv. Tech. Rept. Ser. CEN/T-74-6: 14 pp.

A survey was conducted of selenium content in fishes of the Central Region fishery, namely Ontario, Manitoba, Saskatchewan, Alberta, and the Northwest Territories. Fish samples were ground and digested in a nitric-perchloric-sulphuric acid mixture. Analyses were performed using the fluorescence measurement of the selenium - 2, 3 - diaminonaphthalene complex extracted into cyclohexane. Interfering elements were masked with EDTA prior to extraction. Selenium ranged from a low of 0.04 mg/kg to a high of 2.00 mg/kg with an average value of 0.33 mg/kg neglecting one result of 3.57 mg/kg obtained from a canned Beluga Whale (Muktuk) sample. The overall average from each area is linked to human population density; values were highest in the high population areas (Great Lakes) and decreased in low population areas (Saskatchewan, Alberta, and the Northwest Territories).

1353. Beasley, T.M. and S.W. Fowler. 1976. Plutonium isotope ratios in polychaete worms. Nature 262:813-814.

Deposit-feeding Nereis diversicolor were exposed to: sediments labelled with Pu-238 and Pu-239 + 240, to sediments collected from a former weapons test site, and to sediments from a nuclear fuel reprocessing plant. No preferential uptake of Pu-238 over Pu-239 + 240 was observed.

1354. Beasley, T.M. and S.W. Fowler. 1976. Plutonium and americium: uptake from contaminated sediments by the polychaete Nereis diversicolor. Marine Biology 38:95-100.

Nereid worms were exposed to marine sediments contaminated with Pu and Am from testing of nuclear devices, or to sediments containing liquid wastes discharged from a nuclear fuel reprocessing plant. In both cases uptake of Pu and Am was about 0.5% of the concentration in sediments. Degree of relative uptake of Pu from both sediment types was comparable; relative uptake of Am from sediments contaminated from waste effluent was greater than that from nuclear test debris sediments. Authors concluded that water may be the primary pathway for Pu accumulation by deposit-feeding worms.

1355. Beaven, G.F. 1946. Effect of Susquehanna River stream flow on Chesapeake Bay salinities and history of past oyster mortalities on upper bay bars. Contrib. No. 68, Ann. Rept., Maryland Bd. Nat. Res.:1-11.

Meteorological and hydrographic evidence suggests that recorded major oyster mortalities at Head-of-the-Bay, Chesapeake Bay, between 1908 and 1946 were associated with low salinities caused by high run-off from the Susquehanna River.

1356. Beck, A.B. 1956. The copper content of the liver and blood of some vertebrates. Australian Jour. Zool. 4:1-18.

Copper in blood and liver of a wide range of vertebrate species did not show phylogenetic trends. Mean liver concentrations from 36 marine and aquatic species, including seal, humpback whale, petrel, penguin, tortoise, crocodile, frog, elasmobranch, and fish ranged from 10 to 256 mg Cu/kg dry fat-free weight. Mean blood concentrations from 13 diverse species ranged from 10.3 to 1.29 mg/l. No differences attributable to sex were observed except in salmon Arripis trutta; males contained 15 mg Cu/kg liver and females 45 mg/kg.

1357. Bellamy, D. 1961. Movements of potassium, sodium and chloride in incubated gills from the silver eel. Comp. Biochem. Physiol. 3:125-135.

Isolated gills from fresh and salt water silver eels, Anguilla anguilla, were incubated aerobically and anaerobically in either tap water or seawater. Net changes in K, Na, and Cl content were determined. Under all conditions, isolated gills were nearly impermeable to K, retaining a K content of 1.6 mg/g wet wt. Gills incubated in freshwater had an initial drop in Na from 1.4 to 1.2 mg/g wet wt, while salt water gills gained Na from an initial 1.9 mg/g to 2.5 mg/g. A constant level of sodium chloride was maintained in isolated gills under aerobic conditions against the normal diffusion gradient to which the eel was adapted. The constant Na content appeared to result from a steady state in which passive diffusion was balanced by an active movement of Na in the opposite direction.

1358. Bellrose, F.C. 1951. Effects of ingested lead shot upon waterfowl populations. Trans. 16th North Amer. Wildl. Conf.:125-135.

Of 4561 mallards trapped during autumn of 1949 and 1950, an average of 7.69% contained ingested lead shot, with the percentage increasing as the hunting season progressed. Ducks fed one shot and then released averaged about 9.0 km per day before being shot; those fed two shots travelled 6.7 km per day. Control ducks averaged 11.3 km daily before being shot. Of ducks banded and released in 1950, the total amount of bands returned by hunters were 11% for controls, 14% for ducks fed one shot, and 22% for ducks fed two pellets.

1359. Benayoun, G., S.W. Fowler, and B. Oregioni. 1975. Flux of cadmium through euphausiids. Marine Biology 27:205-212.

In 15 days, Megancytiphanes norvegica accumulated Cd-109 by a factor of 180 directly from water and 240x from a water and food (Artemia) milieu. Approximately 10% of ingested Artemia Cd-109 was incorporated into internal tissue. After 1 month, Cd accumulated directly from water was most concentrated in viscera with lesser amounts in eyes, exoskeleton and muscle. Cd concentration from ingested food increased nearly 5x during passage through M. norvegica and accounted for 84% of total Cd flux through the euphausiid. Fecal pellet deposition is the principle downward Cd transport mechanism by this species. Natural euphausiids had Cd concentrations in mg/kg dry wt, of 0.7 in whole animal, 2.1 in molts, 9.6 in feces and 0.3 in eggs. Food, consisting of phytoplankton, microcrustacea and detritus had 2.1 mg Cd/kg dry wt.

A simple model, assuming that Cd intake equals Cd released plus that accumulated in tissue, allowed assessment of various metabolic parameters in controlling Cd flux through euphausiids.

1360. Bender, J.A. 1975. Trace metal levels in beach dipterans and amphipods. Bull. Envir. Contamin. Toxicol. 14(2):187-192.

Over a seven week period beach hoppers *Orchestoidea corniculata* and marine flies (*Coelopa vanduzeei*, *Fucellia rufitibia*) from four California beach sites were analyzed for trace element levels. Flies showed consistently higher levels of Zn, Fe, Cu, and Cd than hoppers. The approximate ranges (in mg/kg) in flies and hoppers, respectively, were: Zn 150->300 and 60-120, Fe 100-225 and 30-115, Cu 10-125 and 5-70, Cd 40-150 and 10-30. Manganese was low (<10 mg/kg) in all beach arthropods tested. Lead, nickel, and silver occurred only in trace amounts. Metal levels were similar in adult and juvenile hoppers. No difference was found between the two species of marine flies. Iron levels in the hopper fluctuated greatly over time; Cu, Pb, and Zn fluctuated moderately, but Cd, Mn, Ag, and Ni remained stable.

1361. Bender, M.L., R.B. Lorens, and D.F. Williams. 1975. Sodium, magnesium and strontium in the tests of planktonic foraminifera. Micropaleontology 21:448-459.

Na/Ca, Mg/Ca and Sr/Ca atom ratios of planktonic foraminifera analyzed from sediments of the North Atlantic and Tasman Sea ranged from 1.2×10^{-3} to 7.1×10^{-3}. Na and Sr appear to be homogenously distributed throughout the test; Mg is more variable. Na/Ca, Mg/Ca, and Sr/Ca atom ratios of individual species from an Upper Pleistocene core section in the Tasma Sea decrease with increasing growth depth of each species. Atom ratios of *Globigerinoides sacculifer* and *G. ruber* samples from recent North Atlantic sediments vary similarly to those of Tasman Sea sample, but do not show any statistical temperature dependence. Na/Ca and Sr/Ca atom ratios in the foraminiferal calcite are higher by a factor of 5 to 10 than predicted from distribution coefficient data; Mg/Ca atom ratios are lower than predicted, assuming crystal growth occurs in a solution of composition similar to sea water.

1362. Bengtsson, B.-E. 1974. The effect of zinc on the ability of the minnow, *Phoxinus phoxinus* L., to compensate for torque in a rotating water-current. Bull. Environ. Contamin. Toxicol. 12(6):654-658.

"Critical rpm"—defined as the point when a fish, unable to compensate for the torque of a rotating flow, is forced to rotate—was determined for underyearlings, yearlings, and mature fish exposed to sublethal concentrations of zinc. For underyearlings, mean critical rpm decreased significantly at zinc levels of 0.06 mg/l and 0.16 mg/l after 108 days of exposure. After 109 days, yearlings exposed to 0.16, 0.33, and 0.78 mg/l Zn exhibited lower critical rpm's than controls; no effect was observed at 0.06 mg/l. Yearlings were also less sensitive after 150 days of exposure to Zn; only 0.30 mg/l level producing a decrease. Adults showed decreases at levels of 0.20 and 0.31 mg/l after 100 days; after 270 days of exposure only 0.30 mg/l level produced a reduction. Reduced swimming ability may be caused by vertebral damage.

1363. Bengtsson, B.-E. 1974. The effects of zinc on the mortality and reproduction of the minnow, Phoxinus phoxinus L. Arch. Environ. Contamin. Toxicol. 2:342-355.

Long-term effects of zinc nitrate on reproduction and mortality during different developmental stages of the freshwater teleost Phoxinus phoxinus were studied. Mortality of newly-hatched fry was the most sensitive parameter when compared to: numbers of eggs deposited; hatchability; and mortality of underyearlings, yearlings and mature minnows. Fry showed an increased mortality at a Zn concentration of 0.08 mg/l, which is 1/40th of the 96-hr LC-50 estimated for adults.

1364. Bengtsson, B.-E. 1974. Vertebral damage to minnows Phoxinus phoxinus exposed to zinc. Oikos 25:134-139.

Adult minnows exposed to different concentrations of $Zn(NO_3)_2$ in fresh water, developed hemorrhages and lesions. Vertebral damage occurred between 0.20 and 2.4 mg/l of Zn; this is below the LC-50(96h) value of 3.2 mg/l. The striking similarity between symptomology of zinc and that produced by organophosphate compounds is discussed.

1365. Bengtsson, B.-E. 1974. Effect of zinc on the movement pattern of the minnow, Phoxinus phoxinus L. Water Research 8:829-833.

A shoal of 30 minnows developed hyperactivity as a response to a gradually increased zinc concentration from 0.00 to 0.39 mg Zn/l. The increase in rate of activity seems to be more closely related to rate of increase in concentration of Zn, rather than concentration itself. This behavior was followed by a period when the fish displayed hypoactivity. Besides quantitative alterations in activity there were also changes in the distribution between diurnal and nocturnal activity.

1366. Bengtsson, B.-E. 1974. Effect of zinc on growth of the minnow, *Phoxinus phoxinus*. Oikos 25:370-373.

Reduced growth occurred in yearlings and adults of this freshwater fish following exposure over a 150-day period to <0.02, 0.05, 0.13, 0.20, and 0.30 mg/l of zinc, as zinc nitrate. Yearlings were more sensitive than adults and showed reduced growth at 0.13 mg/l Zn as compared to 0.20 mg/l for adults; these values correspond to 1/25 and 1/16 of the estimated LC-50 (96 hr), respectively. Suppressed growth was associated with reduced *Tubifex* consumption.

1367. Bengtsson, B.-E., C.H. Carlin, A. Larsson, and O. Svanberg. 1975. Vertebral damage in minnows *Phoxinus phoxinus* L. exposed to cadmium. Ambio 4:166-168.

The 70-day continuous flow LC-50 value for *Phoxinus* and cadmium chloride at 6°/oo salinity and 12.9 C was 0.420 mg/l Cd^{2+}; the LC-50 (96 hr) value was 39.0 mg/l Cd^{2+}. About 30% of all survivors at 70 days developed lesions in the spinal column; these injured fish survived due to adequate shelter, food, and lack of enemies in test aquaria, but probably would have died under natural conditions. Concentrations as low as 0.0075 mg/l were sufficient to produce vertebral damage; about 33% of the survivors exhibited damage at 0.100 mg/l; maximum number of vertebral abnormalities (67%) were associated with 0.960 mg/l of Cd^{2+}. There were no spinal deformations in controls.

1368. Benijts-Claus, C. and F. Benijts. 1975. The effect of low lead and zinc concentrations on the larval development of the mudcrab, *Rhithropanopeus harisii* Gould. *In*: Koeman, J.H. and J.J.T.W.A. Strik (eds.). Sublethal effects of toxic chemicals on aquatic animals. Elsevier Sci. Publ. Co., Amsterdam: 43-52.

Up to 50 ug/l of Zn^{2+} or Pb^{2+} significantly delays larval development of mudcrabs. Mean development time, in days, from hatch to megalopa stage was 14.35 in controls, 15.40 for 25 ug Zn^{2+}/l, 15.20 for 50 ug Zn^{2+}/l, 14.56 for 25 ug Pb^{2+}/l, 15.40 for 50 ug Pb^{2+}/l, but only 13.48 for a mixture of 25 ug Zn^{2+}/l and 25 ug Pb^{2+}/l, and only 14.73 for a mixture of 50 ug Zn^{2+}/l and 50 ug Pb^{2+}/l. The effect of Pb^{2+} masks that of Zn^{2+} when mixtures are tested. Some combinations neutralize toxic effects of lead and may even accelerate larval growth.

1369. Beninson, D., E.V. Elst and D. Cancio. 1966. Biological aspects in the disposal of fission products in surface waters. *In*: Disposal of Radioactive Wastes into Seas, Oceans and Surface

Waters, Int. Atom. Ener. Agen., Vienna, Austria:337-354.

Studies conducted by the Argentine Atomic Energy Commission on uptake of fission products, including isotopes of Ca, Ce, Cs, K, Ru, Sr, and Zr, by fresh water teleosts, molluscs, crustaceans and vascular plants are summarized. In transfer of Sr via aquatic food chains, Sr-to-Ca discrimination factors were more significant for risk estimation than concentration factors (CF). Vascular plants slightly prefer Sr to Ca with discrimination factors (DF) ranging from 1.0 to 2.5. Molluscs and freshwater discriminate against Sr with factors ranging from 0.35 to 0.75 according to species; DF hold over a wide range of Ca and other ion concentrations in water, and allow reliable predictions of biota levels. Cesium-to-potassium ratios were dependent on K concentration. Uptake of Cs is therefore characterized by CF. Aquatic vascular plants substantially concentrate Cs, Ru, Zr and rare earth radionuclides; CF ranging from 200 to 30,000 according to species and nuclide. Particularly important concentrations are found for Ce. Molluscs and teleosts have much lower CF for these nuclides (from 10 to a few hundreds).

In field conditions, substantial fractions of disposed activities are removed from water by exchange with bottom materials and sedimentation of suspended particles carrying radioactivity. Results in natural ponds with low water-renewal rates show removals of 90% of Cs, 40% of Ru, 60% of Zr and 90% Ce radionuclides. Some species tested were reasonably good indicators, including "present level indicators" which follow changes in environment and "integrating monitors" which relate cumulative environmental contamination.

1370. Benoit, D.A. 1975. Chronic effects of copper on survival, growth, and reproduction of the bluegill (Lepomis macrochirus). Trans. Amer. Fish. Soc. 104(2):353-358.

During 22-month exposure of sunfish to copper in soft water, survival of adults was reduced, growth retarded, and spawning inhibited at 162 ug/l of copper. Tissue residue analysis of gill, kidney, and liver indicated that Cu had accumulated in some or all of these tissues at test water concentrations of 40 to 162 ug Cu/l. Copper residues in brain, spleen, gonad and muscle tissue of fish exposed to 162 ug Cu/l did not differ significantly from residues in controls. Survival of larval fish after exposure for 90 days to copper was adversely affected at 40 to 162 ug Cu/l. The maximum acceptable toxicant concentration of copper to this species in water with a hardness of 45 mg/l and pH range 7 to 8 lies between 21 and 40 ug Cu/l, or 1.9 to 3.6% of the mean 96-hr LC-50 for juveniles (1,100 ug Cu/l).

1371. Benoit, D.A. 1976. Toxic effects of hexavalent chromium on brook trout (*Salvelinus fontinalis*) and rainbow trout (*Salmo gairdneri*). *Water Research* 10:497-500.

Brook trout exposed for 22 months and rainbow trout for 8 months to hexavalent chromium showed increased alevin mortality at 0.35 mg/l and temporarily retarded growth at 0.10 mg/l, the lowest level tested. Reproduction and embryo hatchability of brook trout were unaffected at Cr^{+6} concentrations deleterious to survival of newly hatched alevins. Maximum acceptable toxicant concentration for brook and rainbow trout exposed to Cr^{+6} in water with a hardness of 45 mg/l (as $CaCO_3$) and a pH range of 7-8 lies between 0.20 and 0.35 mg Cr/l. LC-50 (96 h) values for brook and rainbow trout were 59 and 69 mg Cr^{+6}/l, respectively.

1372. Benoit, D.A., E.N. Leonard, G.M. Christensen, and J.T. Fiandt. 1976. Toxic effects of cadmium on three generations of brook trout (*Salvelinus fontinalis*). Trans. Amer. Fish. Soc. 105: 550-560.

Three generations of trout were exposed to cadmium at different concentrations ranging between 0.06 and 6.4 ug Cd/l. Cadmium at 3.4 ug/l caused significant numbers of deaths in first-and second-generation adult males during spawning, and retarded growth of juvenile second-and third-generation offspring. In Lake Superior water (hardness 44 mg/l as $CaCO_3$, pH 7-8), the maximum allowable toxicant concentration fell between 1.7 and 3.4 ug Cd/l. Kidney, liver and gill tissue accumulated the greatest amounts of cadmium which reached an equilibrium concentration in first- and second-generation trout after 20 weeks. No increases in Cd were found in edible muscle in any Cd concentration tested. Cadmium loss from gill tissue of second-generation trout was rapid after transfer to Cd-free water for 12 weeks but there was no loss from liver and kidney.

1373. Benoit, R.J., J. Cairns, Jr., and C.W. Reimer. 1968. A limnological reconnaissance of an impoundment receiving heavy metals, with emphasis on diatoms and fish. Reservoir Fish. Resources Symp., Amer. Fish Soc., Apr. 5-7, 1967: 31 pp.

Causes of fishkills occurring sporadically below a reservoir near Redding, California, were investigated. A survey indicated that upper tributaries of the reservoir had typical varieties of flora and fauna but a lower tributary and its two branches were severely degraded by acid mine drainage. This degrading influence was also detected at the lower portion of the reservoir and upper portion of a lake which lies below the reservoir. Diatometer surveys confirmed these results and indicated increased damage to diatom flora in the lower portion of the reservoir and upper portions of the lake during high water flow due to dam regulation. Waters of the lower tributary had very low pH and high concentrations of iron (up to 512 mg/1), zinc (up to 164 mg/1), and copper (up to 64 mg/1). Delta muds of this tributary also contained high levels of Fe (170 and 126 mg/g), Zn (3.5 and 2.9 mg/g) and Cu (0.2 and 0.1 mg/g dried mud). Large quantities of hydrous iron oxides were sedimented in the reservoir below the tributary entrance.

LC-50's were determined for waters from the branches of the lower tributary and for suspensions of tributary mud. LC-50 (48 hr) values for native chinook salmon Oncorhynchus tschawytscha, ranged from 1.33 to 0.56% test water in dilution water. For hatchery fish these values were 0.55% to 0.56%. In the lower tributary, LC-50 was 8.3% for both native and hatchery fish. Results show that both tributary water and delta sediments were toxic; analysis of flow conditions indicated that toxic conditions could also develop in the lower reservoir and upper lake due to acid water and heavy metals discharged from the tributary.

1374. Benson, W.W., D.W. Brock, J. Gabica, and M. Loomis. 1976. Swan mortality due to certain heavy metals in Mission Lake area, Idaho. Bull. Environ. Contamin. Toxicol. 15:171-174.

Swans Olor columbianus found dead in the Mission Lake area of lower Couer d'Alene river valley in Idaho were autopsied and analyzed for lead. Mean Pb levels in mg/kg wet wt from 13 swans were 74.5 in spleen, 45.1 in kidney, 40.3 in bone, 8.6 in heart, 8.9 in brain, and 11.0 in flesh. Lead poisoning probably resulted from local mines and smelters. Only one bird had lead shot in the gizzard. Authors state that ingestion of Pb contaminated vegetation is the probable cause of death.

1375. Benson, W.W., D.W. Brock, J Gabica, and M. Loomis. 1976. Pesticide and mercury levels in pelicans in Idaho. Bull. Environ. Contamin. Toxicol. 15:543-546.

Twelve white pelicans Pelicanus erythrorhynchos were collected and analyzed for mercury and pesticide residues. Mean Hg content in mg/kg wet wt was 12.5 for liver, 3.7 for feathers, 3.8 for kidney, 2.3 for heart, 0.3 for bone, 3.4 for muscle, and 1.2 for brain. Since Hg concentrations in fish from the same area ranged from 0.12 to 0.94 mg/kg wet wt, it was concluded that pelicans accumulated Hg from their fish diet.

1376. Benson, W.W., W. Webb, D.W. Brock, and J. Gabica. 1976. Mercury in catfish and bass from the Snake River in Idaho.

Bull. Environ. Contamin. Toxicol. 15:564-567.

Catfish Ictalurus punctatis, and bass Micropterus dolomeieu, of different age groups from impounded and free flowing sections of the Snake River in Idaho were analyzed for mercury. An increase was observed in Hg content from 0.59 to 0.72 mg/kg wet wt, between two and four year old bass from impounded waters, and 0.67 to 1.15 mg/kg wet wt, for the same age period in free flowing waters. There was an increase in mean values from 0.65 to 0.79 for bass from impounded to free flowing waters. For catfish, both trends seemed to be reversed. Mercury concentration for catfish decreased from 0.60 to 0.51 mg/kg wet wt, between ages 5 and 8 yrs in impounded waters, and from 0.36 to 0.27 mg/kg wet wt for the same year classes in free flowing waters.

1377. Bentley, P.J., J. Maetz and P. Payan. 1976. A study of the unidirectional fluxes of Na and Cl across the gills of the dogfish, Scyliorhinus caniculata (Chondrichthyes). Jour. Exp. Biol. 64:629-637.

Dogfish gills were more permeable to Cl than to Na. Net accumulation of Cl could be accounted for by diffusion along observed electrochemical gradient but Na movement was more consistent with an electrically neutral active Na transport mechanism. When external pH was changed from 7.8 to 6.9 influxes of Na and Cl were depressed, effluxes were unaffected, and fish became slightly less electronegative. In artificial solutions in which concentrations of Na and Cl were lowered and replaced with urea to maintain total osmotic concentration, Na influx displayed saturation kinetics, while Na efflux increased with decreasing Na concentrations. Cl influx decreased linearly but Cl efflux remained constant. Efflux of Cl could not be reconciled with a process of passive diffusion along any of the observed electrochemical gradients and this could reflect presence of an active transport mechanism.

1378. Berg, A. 1968. Studies on the metabolism of calcium and strontium in freshwater fish. I. Relative contribution of direct and intestinal absorption. Mem. Ist. Ital. Idrobiol. 23: 161-196.

Using Sr-85 as a tracer added to water or food, exchange rates were estimated for Ca and Sr in goldfish Carassius auratus. A depressed exchange rate occurs in starved fish when compared to fish fed a maintenance ration. Accumulation of Sr-85 is constant over a wide range of Sr concentrations in water and food. For stable Sr, exchange rate is directly proportional to these concentrations. Ca exchange rate from food is proportional to Ca levels in food, but Sr exchange rate for a definite Sr concentration in food is reduced by increasing Ca levels in food. An inverse proportionality was found between accumulation rate of Sr-85 and Ca concentration in water. Resulting accumulation rate of Ca may be considered as constant over a range of 2.3 mg Ca/l to 23 mg Ca/l in water. In presence of Ca in food, accumulation rate of Ca from water increases regularly with Ca concentration in water. In natural conditions, where Sr/Ca ratio in food is lower than in water, and Ca concentration in food does not exceed 4,000 mg/kg, contribution of direct exchange for Ca and Sr is >80% for Lake Maggiore water (22-23 mg/l Ca) and >65% for Ca concentration in water as low as 4.5 mg/l. Scales are the most important tissue in fish for Ca and Sr exchange. This exchange in scales is due to direct absorption through gills and secondary accumulation in scales via blood.

1379. Berg, A. 1969. Use of Sr-85 for the determination of the contribution of direct and intestinal absorption of Ca and Sr in freshwater fish. *In*: Environmental Contamination by Radioactive Materials. Proc. Seminar. IAEC, Vienna: 325-338.

Ca and Sr exchanges were studied in goldfish under conditions of zero growth. Exchange rate from water increased asymptotically with Ca concentration in water when Ca concentration in food equalled 8000 mg/kg; this is constant when Ca concentration in food is zero. Exchange rate of Ca from water into fish body is not dependent on absolute value of influx rate from water but on value of ratio between influx rate from water : total influx rate from water and food.

1380. Berg, W., A. Johnels, B. Sjostrand, and T. Westermark. 1966. Mercury content in feathers of Swedish birds from the past 100 years. Oikos 17:71-83.

Tail feathers from 11 species of birds dating back to 1829 were analyzed for Hg. During the years 1840-1940, levels varied between species but were roughly constant with each species. Differences between species were due primarily to different food chains. In the 1940's Hg levels increased 10-20x. The main Hg sources commencing in the 1940's were the methyl-Hg compounds, and these were chiefly responsible for the increase. The mean level for the white-tailed eagle *Haliaetus albicilla* from 1832 to 1940 was 6600 ng/g, with a range of 2700 to 15,000 ng/g. In 1965 these fish-eating sea eagles had Hg levels as high as 65,000 ng/g, with Hg concentrations in eggs of 5,000 to 11,000 ng/g; eggs with these levels seldom hatched.

1381. Berland, B.R., D.J. Bonin, V.I. Kapkov, S.Y. Maestrini and D.P. Arlhac. 1976. Action toxique de quatre metaux lourds sur la croissance d'algues unicellulaires marines. C.R. Acad. Sci. Paris, t. 282, Ser. D: 633-636. (In French.)

Chloride salts of Hg, Cd, Cu, and Pb were tested against 18 species of unicellular marine alga. Concentrations causing growth inhibition after 17 days at 20 C, in ug metal/l, ranged from <5 to 15 for Hg, 5 to 250 for Cd, 10 to 500 for Cu, and 250 to 2000 for Pb. Lethal concentrations during this same interval ranged from 10 to 25 ug/l for Hg, 50 to >1000 ug/l for Cd, 20 to >1000 ug/l for Cu, and 2000 to >2000 ug/l for Pb. Dinoflagellates were comparatively sensitive to copper.

1382. Bernhard, M. and A. Zattera. 1975. Major pollutants in the marine environment. In: Pearson and Frangipane (eds.). Marine Pollution and Marine Waste Disposal. Pergamon Press, New York: 195-300.

Data are reviewed, summarized, and tabulated on concentrations of Hg, Cd, Pb, Cu, Ni, Zn, Cr and As in seawater, sediments and various groups of marine biota—including algae, higher plants, crustacea, bryazoa, coelenterata, mollusca, teleosts, echinoderms, annelids, mammals, and fish-eating birds. Toxicity of these and other compounds (pesticides, petrochemicals, detergents) to marine organisms are tabulated and reviewed. Calculations are presented on maximum permissible weekly intake of various pollutants by man; results suggest that Hg intake from fish is excessive for certain minorities such as fishermen and their families.

1383. Bernheim, F. 1971. The effect of cyanogen iodide and mercuric chloride on the permeability of cells of *Pseudomonas aeruginosa* and the antagonistic action of sulfhydryl compounds. Proc. Soc. Exp. Biol. Med. 138:444-447.

Mercurials increased swelling rates of *P. aeruginosa* in NaCl to a much greater extent than sodium sulfate; sodium phosphate had an intermediate effect. The rapid but reversible reaction of $HgCl_2$ with cell sulfhydryl groups makes possible determination of degree of penetration of various antagonists to different sulfhydryl sites. Mercuric chloride reacts with 30-50% of all available reactive sulfhydryl groups in cell within 10 sec of incubation at 23 C, with 80-90% reacting in 9 min. These rapidly reacting sulfhydryl groups can be considered to be on or near the surface of the membrane and probably also react with nonpenetrating p-hydroxymercuribenzoate. The more slowly reacting sulfhydryl may be in the membrane or prevented from reacting rapidly by steric hindrance. Since effect of Hg is reversible, the antagonist should be equally effective regardless of time of its addition if the antagonist has access to all sites of interaction. This is true for mercaptoethylamine, cysteine hydantoin, and dithiothreitol, but not for cysteine. This compound cannot apparently penetrate the membrane very far because it becomes increasingly less effective in reversing effect of Hg as latter is allowed to react for longer periods of time with cells.

1384. Bertine, K.K. and E.D. Goldberg. 1972. Trace elements in clams, mussels, and shrimp. Limnology and Oceanography 17:877-884.

Compositional changes in trace element content of shells of mussels and clams that might be related to man's influence on the composition of inshore marine waters over the past hundred years were sought but not found. The following average values were found in the clams Ensis arcuatus and E. siliqua, respectively, in mg/kg dry wt: Fe 66 and 75; Co 0.034 and 0.035; Sb 0.028 and 0.014; Zn 1.40 and 0.84; Sc 0.005 and 0.008; Se 0.060 and 0.033; Ag 0.022 and 0.017; Cr 0.14 and 0.13; and Hg 0.11 and 0.10. Values for the mussel, Mytilus edulis, also in mg/kg dry wt, for both shell and fresh soft part (1971 specimens only) were, respectively: Fe 8.9 and 776; Co 0.029 and 1.74; Sb 0.022 and 0.11; Zn 0.59 and 40; Sc 0.004 and 0.19; Se 0.046 and 4.5; Ag 0.006 and 0.15; Cr 0.10 and 1.23; and Hg 0.49 and 0.97. Contamination from preservatives was evident in shells and tissues of museum specimens. Elemental concentrations in calcareous shells, both aragonitic and mixed aragonitic-calcite, are similar and may reflect composition of waters in which they lived, rejection by organisms, or surface associated features.

Proteinaceous molts of shrimp contained high levels of these elements, in agreement with previous investigations. These levels in molts (as compared to tissue levels), in mg/kg dry wt, were: Rb 3.2 (4.8); Fe 32 (62); Co 0.47 (0.46); Sb 0.03 (0.15); Zn 76 (39); Se 5.0 (6.1); Ag 1.1 (0.24); and Hg 1.3 (1.3). With 20 to 25 molts/shrimp/year, the molting shrimp discharges its body burden of trace elements at least 20 to 25 times, causing a significant redistribution of these elements within the marine environment.

1385. Bertrand, G. 1902. Sur l'existence de l'arsenic dans l'organisme. Compt. Rend. Acad. Sci. (Paris) 134:1434-1437.

Arsenic was normally present in many species of birds and mammals including thyroid glands of seals Phoca barbata captured off Spitzberg; seal thyroids contained about 0.2 mg As/kg wet wt.

1386. Bertrand G. 1902. Sur l'existence de l'arsenic dans la serie animale. Compt. Rend. Acad. Sci. (Paris) 135:809-812.

Arsenic, in mg/kg dry wt, ranged between 0.05 and 0.15 for various and diverse tissues of marine organisms collected at depths up to 1800 m between Gibralter and the Azores. Tissues examined included skin of killer whale Orca gladiator; feathers of petrals (birds); skin, muscle or scales from several species of fishes and elasmobranchs; whole cuttlefish, holothurians, sea urchins, anemones, starfish, and sponge; and soft parts of gooseneck barnacles.

1387. Bertrand, G. and R. Vladesco. 1921. Sur les causes de variation de la teneur en zinc des animaux vertebres: influence de l'age. Compt. Rend. Acad. Sci. (Paris) 172:768-770.

Individuals of 3 species of fishes were analyzed for whole body zinc. Ide Idus orfus, of age 7, 19, and 33 months, contained 142, 36, and 18 mg Zn per kg wet wt, respectively. For tench of age 7, 19, 33, and 84 months, Zn was 60, 81, 88, and 31 mg/kg wet wt, respectively. In herring, smaller fish contained 22 and larger herring 50 mg Zn/kg wet wt. These results do not conform exactly to the general conclusion based on other studies conducted by authors with birds and mammals that body burdens of zinc decrease with increasing age.

1388. Bertrand, G. and R. Vladesco. 1923. Sur la teneur en zinc du corps et de certains organes des invertebres. Bull. Soc. Chim. France 33:341-345.

Zinc in mg/kg wet wt in whole body meats and selected tissues was determined for several species of marine molluscs and crustaceans. Whole oyster Ostrea edulis ranging in age from 18 months to 4 years contained 16 to 27 mg/kg; values were considerably higher for Portuguese oysters Gryphea angulata of similar age range: 500 to 1310 mg/kg. Zinc content of other bivalve molluscs including mussels, clams, cockles, and scallops did not exceed 35 mg/kg except scallops (93 mg/kg). Gastropod molluscs, including the land snail Helix asperata, squid Sepia officianilis, and lobster were all below 59 mg Zn/kg whole body wet wt. Mantle tissue of 4-year old Portuguese oysters contained up to 1074 mg Zn/kg wet wt, but this was quite variable. Edible muscle of crabs and other crustaceans did not exceed 67 mg Zn/kg wet wt.

1389. Betzer, N. and Y. Kott. 1969. Effects of halogens on algae - II. Cladophora sp. Water Research 3:257-264.

Along with halogens, copper sulphate was tested for its effects on the filamentous algae Cladophora sp. Copper sulphate had no effect in 24 hrs at concentrations below 20 mg/l. At 20 mg/l there was slight leaking of cell content through cell wall after 3 hrs. This effect became stronger at 50 mg/1, along with contraction of cytoplasm and change in cell morphology after 24 hrs. At 100 mg/1 these effects were more pronounced at longer exposure periods. A concentration of 5 or 10 mg/1 $CuSO_4$ was fatal: all algae died in 4 days; 40 mg/1 $CuSO_4$ at 5 hrs was also lethal. Penetration of $CuSO_4$ into algal cell caused total enzymatic inhibition, with chlorophyll disappearing and cell becoming discolored.

1390. Betzer, S.B. and M.E.Q. Pilson. 1975. Copper uptake and excretion by Busycon canaliculatum L. Biol. Bull. 148:1-15.

Pathways of copper into the gastropod Busycon canaliculatum and sites of accumulation were investigated in uptake experiments using Cu-64. Routes of possible copper loss were investigated in excretion experiments and by determination of copper content of egg capsules. Uptake of dissolved Cu-64 followed a smooth curve, slowing with time. About 2/3 of the available Cu-64 was absorbed by 48 hr; the rate was proportional to concentration of the medium. Among soft tissues, Cu-64 appeared first on gills, which in 1 hr reached a normalized concentration 100 times that initially present in the medium, and in the blood and kidney (normalized concentration = 1 at 1 hr). By 6 hr Cu-64 appeared in gut and digestive gland (normalized concentration = 5). Cu-64 continued to accumulate in digestive gland; by 48 hr, this tissue contained 50% of the total copper taken up by gill and organs comprising visceral mass. Transfer of absorbed copper to digestive gland continued even when whelks were removed to unlabeled seawater for 24 hr. Separations carried out on blood from whelks labeled with Cu-64 indicated that the absorbed copper in the blood was nonspecifically bound to hemocyanin. Excretion rates for copper averaged 7 ug/24 hr per 100 g fresh tissue weight, and appeared unaffected by the copper concentration of the medium. Under normal environmental copper concentrations, rates of dissolved copper uptake and of copper excretion are probably about equal. The average copper content of egg capsules was 23 ug/capsule. Spawning may be a significant route for copper loss, and an increase in copper excretion in autumn is also suggested as an explanation for a drop in tissue copper concentrations at this season.

1391. Betzer, S.B. and P.P. Yevich. 1975. Copper toxicity in Busycon canaliculatum L. Biol. Bull. 148:16-25.

The effects of high concentrations of copper in seawater upon the gastropod Busycon canaliculatum were followed histologically, by determination of tissue Cu concentrations, and by tracing uptake with Cu-64. Whelks showed a high resistance to ionic Cu, with a tolerance limit between 200-500 ug/1 at normal habitat temperatures for the exposure periods used (54-77 days). At lethal concentrations of 500 and

1000 ug/1, Cu was accumulated by gill and osphradium; these tissues also showed progressive histopathologic change, consisting of swelling of gill filaments, amebocytic infiltration of connective tissues, and necrosis and sloughing of mucosa.

1392. Bieri, R. and D.M. Krinsley. 1958. Trace elements in the pelagic coelenterate, *Vellela lata*. Jour. Mar. Research 16:246-254.

Trace element content for whole body of *V. lata*, expressed as percent of ash, ranged from 5.0 to 7.1 for Mg, 0.56 to 5.6 for Ca, 0.16 to 0.36 for Al, 0.071 to 0.22 for Cu, 0.0007 to 0.0041 for Mn, 0.0033 to 0.022 for Ni, and 0.046 to 0.14 for Ti. Conversion factors are given to convert ash weight to dry or wet wt. Other elements measured qualitatively were in concentrations greater than the following limiting sensitivities, in mg/kg: Fe 10, Si 10, Cr 100, Sr 200, V 70, Ba 100, Ag 3, Pb 10, and Mo 10.

1393. Biesiot, P. and A. Venkataramiah. 1974. Effect of salinity on behavior and survival of postlarval shrimp, *Penaeus aztecus* in relation to ageing. Amer. Zool. 14:1259.

"Normal," "critical" and "lethal" salinity tolerance ranges of postlarval shrimp acclimated to 32^{o}/oo were determined by direct transfer to 16 test salinities ranging from 1.8 to 36^{o}/oo. Effects of acclimatization to intermediate concentrations (25 and 18^{o}/oo) on salinity tolerance were also determined. Testing began with 10 day postlarvae (6.0 mm) and repeated at 3 day intervals up to 31 days when larvae were 19.6 mm. Salinity tolerance in young shrimp was size and age dependent; large postlarvae had a wider normal range than smaller shrimp of identical age. Normal tolerance range expanded as shrimp became older. By acclimation, postlarvae from 18 and 25^{o}/oo extended their tolerance to very low salinities at a younger age than those from 32^{o}/oo S. At 19 days shrimp initiated escape behavior from the stress, the strength of which increased with age. This reaction plus greater survival rates for older and larger animals suggest the gradual development of osmosensitive and osmoregulatory mechanisms enabling shrimp to withstand reduced salinity. The impact of heavy spring rain on summer shrimp populations is discussed.

1394. Billen, G., C. Joiris and R. Wollast. 1974. A bacterial methylmercury-mineralizing activity in river sediments. Water Research 8:219-225.

A bacterial activity involving mineralization of methylmercury was observed in bottom sediments of the river Sambre in Belgium, in a zone heavily polluted with inorganic mercury. After 90 hrs incubation with an initial concentration of 1000 bacteria/ml and 85 ug Hg/l as methylmercury, the methylmercury decreased to <10 ug Hg/l while metallic mercury increased from <5 ug Hg/l to 40 ug Hg/l. Bacterial density dropped to 30/ml after 15 hours. At this point, mercury resistant bacteria were selected with exponential growth observed until final density of 5 x 10^6 bacteria/ml was reached. Mineralizing capacity of the community can be increased in response to increased concentrations of methylmercury, through selection of methylmercury-resistant bacterial species, among which organisms responsible for methylmercury mineralization constitute only a part. Authors suggest that some equilibrium can be reached between degradation of methylmercury and its addition to, or its production in, mercury polluted environments.

1395. Birdsong, C.L. and J.W. Avault, Jr. 1971. Toxicity of certain chemicals to juvenile pompano. Prog. Fish-Cult. 33:76-80.

Toxicity of therapeutic chemicals routinely used in parasite and disease control, including copper sulfate, acriflavin, formalin, and potassium permanganate was determined for juvenile pompano, Trachinotus carolinus at different salinities. LC-50 (96 hr) values in mg/kg of copper sulfate at salinities of 10, 20 and 30^{o}/oo were 1.4, 1.5 and 2.0, respectively. LC-50 (96 hr) values, in mg/kg of potassium permanganate at salinities of 10, 20 and 30^{o}/oo were 2.9, 1.6 and 1.6, respectively, and demonstrated that pompano were more sensitive to permanganate at increased salinities.

1396. Birke, G., A.G. Johnels, L.O. Plantin, B. Sjostrand, S. Skerfving and T. Westermark. 1972. Studies on humans exposed to methylmercury through fish consumption. Arch. Environ. Health 25: 77-91.

Humans exposed to methylmercury through consumption of fish were studied during and after varying degrees of exposure. Methyl-Hg comprised half or less of total blood cell Hg in "normal" subjects; this proportion was higher in heavily-exposed subjects. There was a relation between exposure to methylmercury via ingestion of fish with blood Hg levels, and between Hg levels in blood and hair. No symptoms and signs indicating methylmercury poisoning were observed in subjects exposed at most to 0.8 mg of Hg as methyl-Hg per day and having Hg levels up to 1,200 mg/kg blood cells and 185,000 mg/kg hair. After exposure, biologic half-life of Hg was 33 to 120 days in hair and 99 to 120 days in blood cells in 5 and 2 subjects, respectively.

1397. Black, G.A.P., D.J. Hinton, H.C. Johnston, and J.B. Sprague. 1976. Annotated list of copper concentrations found harmful to aquatic organisms. Dept. Environ. Canada, Fish. Marine Serv. Tech. Rept. 603: 44 pp.

A summary is presented of 101 selected papers which relate concentrations of copper in water to deleterious effects on aquatic organisms. Tables containing 169 items are arranged by increasing concentrations for various species of the following groups: fish, amphibia, crustacea, mollusca, insecta, rotifera, protozoa, algae, annelida, echinodermata, and higher plants. Listed concentrations range from 0.01 to 63,500 ug/l. Some findings on toxicities of various forms of copper in water are presented.

1398. Black, V.S. 1951. Changes in body chloride, density, and water content of chum (*Oncorhynchus keta*) and coho (*O. kisutch*) salmon fry when transferred from freshwater to seawater. Jour. Fish. Res. Bd. Canada 8(3):164-177.

Chum and coho salmon fry tolerated 50% seawater (8-9^{o}/oo Cl). Chum fry survived direct transfer from freshwater to seawater (15-17^{o}/oo Cl), but showed a marked increase in body chloride during first 12 hrs, followed by a return to normal between 12 and 24 hrs. Coho, however, died within 36 hrs, after a 60% increase in chloride. Coho fry lost more water than chum fry after introduction to seawater. Density of both species approximated that of the water within an hour of transfer to new medium. When returned to fresh water after 12 hrs in seawater, body chloride, density, and water content of both species regained normal levels within 10 hrs. Coho fry did not permanently acclimatize to seawater in this study.

1399. Blackwelder, P.L., R.E. Weiss and K.M. Wilbur. 1976. Effects of calcium, strontium and magnesium on the coccolithophorid *Cricosphaera* (*Hymenomonos*) *carterae*, I. Calcification. Marine Biology 34:11-16.

Effects of Ca, Sr, and Mg on calcification and mineralogy of calcified bodies of alga *C. carterae* were studied. The capacity of cells to calcify in various concentrations of these ions was examined following preliminary decalcification in CO_2. At a concentration of 0.4 g Ca/l, 75% of cells formed coccoliths within 24 hrs and almost all cells were recalcified after 2 days. At 0.04 or 0.004 g Ca/l, no recalcification occurred. With addition of Sr to Ca-deficient media, calcification took place as shown by observations of coccoliths and Ca analysis; percentage of calcified cells increased with increasing concentrations of Sr. Strontium added to a Ca-deficient media was more effective than an equivalent concentration of Ca; no Sr was deposited in coccoliths. X-ray analysis demonstrated that calcite was deposited by cells in all concentrations of Ca and Sr at which calcification took place. At concentrations of Mg in media from 0.0 to 1.01 g/l, cells retained ability to calcify although calcification was reduced in absence of Mg. In low Mg concentrations (3.12 x 10^{-3} to 1.01 x 10^{-4} g/l), the coccoliths were 60% calcite and 40% aragonite; in absence of Mg, only calcite was formed.

1400. Blake, N.J. and D.L. Johnson. 1976. Oxygen production - consumption of the pelagic Sargassum community in a flow-through system with arsenic additions.. Deep-Sea Res. 23:773-778.

In a laboratory study, metabolism of a Sargassum community (algae, bacteria, coelenterates, crustacea, teleosts) was unaffected by addition of 0.028 mg As^{+5}/l. When steady-state distribution of As species was altered experimentally, the community re-established ambient seawater As^{+3}/As^{+5} ratio.

1401. Blanc-Livni, N. and M. Abraham. 1970. The influence of environmental salinity on the prolactin and gonadotropin-secreting regions in the pituitary of Mugil (Teleostei). Gen. Comp. Endocrinol. 14:184-197.

Two species of Mugil were collected from freshwater, from seawater, and from a hypersaline lagoon. In M. capito, the rostral pars distalis occupied 8% of the total hypophysis in fish from the hypersaline lagoon (7.8°/oo S) and 42% in fish from freshwater. Volumetric changes of proximal pars distalis are the inverse of those of the rostral pars distalis. Proximal pars distalis changes were most pronounced in M. cephalus; this lobe occupied 35% of hypophysis in specimens collected from the Mediterranean Sea during spawning season, as compared with 7% of hypophysis in freshwater specimens. Pituitary prolactin content in M. cephalus was high in freshwater specimens and low in specimens from the sea. Striking histological changes, possibly indicative of a degenerative process, were observed in nucleus lateralis tuberis of M. cephalus confined to freshwater for several years. These changes and their relationship to volumetric variations of rostral and proximal pars distalis of pituitary are discussed. Respective plasma Na levels, in g/l, of M. cephalus and M. capito from freshwater, 35°/oo and 78°/oo salinity were 3.7 and 4.3, 4.1 and 4.8, and 5.3 and 5.1.

1402. Blankenship, M.L. and K.M. Wilbur. 1975. Cobalt effects on cell division and calcium uptake in the coccolithophorid Cricosphaera carterae (Haptophyceae). Jour. Phycol. 11:211-219.

Cell division rate of a calcifying alga increased slightly when cobalt concentration of medium increased from 0 to 0.6 mg/l, above which division rate decreased linearly to zero at 6 mg Co/l. Inhibition of division was reversible after 2 days in Co. Protein content was elevated in Co-treated nondividing cells but at 6 mg Co/l the protein synthesis rate was reduced to 19% of the control culture medium value (5.4 ug Co/l). Cell volume increased with Co concentration; after 72 h in 12 mg Co/l, volume was 3.2x that of culture medium. After 48 h, calcium uptake had increased 53% in 6 mg Co/l and decreased 40% in 12 mg Co/l as compared with cells in 5.4 ug Co/l. Ultrastructurally, Co caused enlargement of cell vacuole and appearance of membrane-bound vacuoles containing electron dense bodies.

1403. Blum, H.F. 1922. On the effect of low salinity on *Teredo navalis*. Univ. Calif. Publ. Zool. 22(4):349-368.

Effects of low salinity on extension of *Teredo* siphons indicate that *Teredo* is normally active in salinities as low as 9°/oo. Below 7°/oo, activity decreases rapidly until at 3°/oo siphon extension ceases. The average lethal salinity for *Teredo* was determined at 5°/oo. Below 5°/oo *Teredos* obtain some temporary protection by stopping the mouth of the burrow with pallets. A period of 33 days below 4°/oo salinity destroyed 90% of *Teredos* in piles at Crockett, California.

1404. Bodansky, M. 1922. La repartition du zinc dans l'organisme du poisson. Compt. Rend. Acad. Sci. (Paris) 173:790-792.

Zinc content in various tissues of two species of marine teleosts was determined. Concentration in mg/kg fresh wt for red snapper *Lutjanus aya* was lowest in muscle (2.3) and highest in spleen (43.5) and liver (55.5); bony tissues were intermediate in value. For catfish *Ailurichtys marinus* muscle was lowest (8.1), bony tissues highest (93-102), and liver intermediate (31).

1405. Bohm, E.L. 1972. Concentration and distribution of Al, Fe, and Si in the calcareous alga, *Halimeda opuntia* (L) (Chlorophyta, Udoteaceae). Int. Revue ges. Hydrobiol. 57:631-636.

Mean concentrations of Si, Al, and Fe in dry *Halimeda* were 0.20%, 0.028% and 0.024%, respectively. Concentration factors of Al, Fe, and Si were 2500, 2500 and 250, respectively. Approximately 90% of the SiO_2 and Al is associated with water insoluble and water soluble organic fractions from the algal cell wall. Passive adsorption rather than active transport is favored for silicate uptake.

1406. Bohm, E.L. 1973. Studies on the mineral content of calcareous algae. Bull. Marine Science 23:177-190.

Maximal mineral contents in g/kg dry wt of calcareous algae were 970 for Halimeda, 600 for Penicillus and Rhipocephalus, and 370 for Udotea. In some species of Halimeda mineral content increased with depth. $MgCO_3$ concentration varied with genus and species, and within different parts of the same organism. In Halimeda, Penicillus, and Rhipocephalus, $MgCO_3$ was 0.2 to 3.0 mol %. In Udotea, $MgCO_3$ was 3 to 4 mol %. In most algae investigated, $MgCO_3$ concentration was higher in younger scarcely calcified segments of the apical region, than in fully developed more heavily calcified segments farther below. Juvenile Udotea and Penicillus contained more $MgCO_3$ than adult individuals. Mean mineral contents, in g/kg dry wt, of H. opuntia, were 14.6 for Na, 0.9 for K, 2.1 for Mg, 311 for Ca and 7.7 for Sr.

1407. Bohn, A. 1975. Arsenic in marine organisms from West Greenland. Marine Poll. Bull. 6(6):87-89.

A baseline study was conducted in a Greenland inlet within 6 km of a lead-zinc mining project which became operational in the fall of 1973. Dry weight As levels in marine biota during summer of 1972 and 1973 ranged from 17 to 307 mg/kg in fish fillets, and from 7 to 512 in fish livers. Arsenic in wolffish, halibut, and sculpin muscle tissues were positively correlated with fish size; this was not observed for liver. For mussel (Mytilus edulis) and rockweed (Fucus vesiculosis) As values were 14 to 16 and 35, respectively. Prawns Pandalus borealis had arsenic levels up to 80 mg/kg in abdominal muscle; this contrasts with the 6 mg/kg reported for planktonic copepods. Arsenic appears to accumulate at higher trophic levels in this ecosystem. Overlapping food habits of wolffish and plaice suggest that arsenic accumulation in these fishes may depend on metabolic characteristics rather than diet exclusively.

1408. Bohn, A. and R.O. McElroy. 1976. Trace metals (As, Cd, Cu, Fe, and Zn) in Arctic cod, Boreogadus saida, and selected zooplankton from Strathcona Sound, Northern Baffin Island. Jour. Fish. Res. Bd. Canada 33:2836-3840.

Average concentrations of As and Zn were higher in Arctic cod fillets at 46 and 34 mg/kg dry wt, respectively, than in livers from the same fish at 4.4 and 19 mg/kg dry wt, respectively. Cd and Fe concentrations were higher in liver at 0.68 and 40 mg/kg dry wt than in fillets, while the Cu concentration in fillets, at 4.0 mg/kg dry wt was not significantly higher than liver. Arsenic and Zn in whole fish, and As in fillets, were positively correlated to body weight, Cu and Fe were negatively correlated and Cd showed no relation. Cd levels in unsorted planktonic copepods were 5.0 mg/kg dry wt which is 5 to 8 x higher than in Arctic cod. As, Cu, Fe and Zn were higher in fish than the levels of 5.6, 3.7, 78 and 60 mg/kg dry wt, respectively, fourd in copepods. Metal levels in amphipods, in mg/kg dry wt were: As 7.9, Cd 7.0, Cu 26, Fe 87, and Zn 43. Average levels in chaetognaths, in mg/kg dry wt ranged in As from 7.5-7.7, Cd 1.2-1.3, Cu 5.6-6.3, Fe 32-33 and Zn 76-90.

1409. Boney, A.D. 1971. Sub-lethal effects of mercury on marine algae. Marine Poll. Bull. 2:69-71.

Sporelings of red alga *Plumaria elegans* were immersed in solutions containing 0.12, 0.25, 0.5, or 1.0 mg/l Hg as $HgCl_2$. A 50% growth inhibition was obtained after 6 hrs in 1 mg/l Hg, 12 hrs in 0.5 mg/l, and 24 hrs in 0.25 mg/l. Survival rates were high during post-exposure. However, longer exposure to 1.0 or 0.5 mg/l Hg killed most sporelings. Organic mercury compounds of n-alkyl mercuric chloride types showed increasing toxicity with increasing number of C atoms in the side chain. After 2.5 min in 0.5 mg/l Hg as $n\text{-}C_3H_7HgCl$, plants showed 50% growth inhibition, and after 5 min, a 70% growth inhibition. With Hg as $n\text{-}C_4H_9HgCl$ greater inhibition was observed. With $n\text{-}CH_3HgCl$ a 50% growth inhibition occurred after 17.5 min immersion in solutions containing 0.08 mg/l Hg; a similar pattern occurred in 0.04 mg/l Hg.

1410. Boney, A.D. and E.D.S. Corner. 1959. Application of toxic agents in the study of the ecological resistance of inter-tidal red algae. Jour. Mar. Biol. Assn. U.K. 38:267-275.

Poisons of high lipid solubility ($n\text{-}C_3H_7HgCl$ and 1:2-naphthoquinone) are far more toxic than one of low lipid solubility ($HgCl_2$) to sporelings of *Plumaria elegans*, *Polysiphonia lanosa* and *Spermothamnion repens*; but when *Antithamnion plumula*, *Ceramium pedicellatum* and *Ceramium flabelligerum* are used the relative toxicities of the poisons are much closer in value. Toxic effects of $HgCl_2$ to sporelings of *Plumaria* develop slowly at normal temperature and more quickly at elevated temperatures. When sporelings of *Antithamnion* are used, toxic effects develop rapidly at both normal and raised temperatures. The relative toxicities of $n\text{-}C_3H_7HgCl$ and $HgCl_2$ to sporelings of *Plumaria*, *Polysiphonia* and *Spermothamnion* are markedly reduced when the test material is first treated with sub-toxic amounts of kerosene, a substance known to distort the lipid moiety of the cell membrane. When *Antithamnion*, *C. pedicellatum* and *C. flabelligerum* are used as the test material, the effect of kerosene is negligible. These results are consistent with the view that proportion of lipid material present in cell membrane is important in determining susceptibility of an intertidal red alga to increased sea-water temperature.

1411. Boney, A.D., E.D.S. Corner and B.W.P. Sparrow. 1959. The effects of various poisons on the growth and viability of sporelings of the red alga *Plumaria elegans* (Bonnem.). Schm. Biochem. Pharmac. 2:37-49.

Exposure of sporelings of *P. elegans* in seawater at pH 8.1 to 1.0 mg/l for one week of mercury, silver, copper or arsenic salts allowed 11, 0, 0, and 18% respectively, to develop as opposed to 77% in controls. After one week, 10 mg/l concentrations of non-metallic inhibitors hydrocyanic, and hydrazoic acid and 50 mg/l concentrations of iodoacetic, flouroacetic and molonic acid and 2:4-dinitrophenol allowed between 33 and 75% of the sporelings to develop, proving to be less toxic than the heavy metals. Toxicities of Hg and As are increased when found in organic compounds. Thus methyl-, ethyl-, n-propyl, n-butyl-, isopropyl-, isoamyl- and phenyl-mercuric chlorides and phenylmercuric iodide are more toxic than mercuric chloride; phenarsazine chloride is more toxic than arsenite. Toxicities of organic derivatives of Hg and As are reduced in presence of an excess of glutathione, which also reduces the toxicity of Cu, Ag and arsenite. When sporelings immersed in toxic solutions of all poisons are subsequently washed with reduced glutathione, toxic effects are diminished. Toxicities of a homologous series of primary n-alkylmercuric chlorides increased to a maximum with $n\text{-}C_3H_7HgCl$. Mercuric iodide was 1.7x more toxic as $HgCl_2$ to adult copepods *Acartia clausi*, and 24x more toxic to brine shrimp, *Artemia salina*; various organic derivatives of Hg were markedly more toxic to crustaceans but not *Plumaria* in presence of excess KI.

1412. Born, J.W. 1968. Osmoregularity capacities of two caridean shrimps *Syncaris pacifica* (Atyidae) and *Palaemon macrodactylus* (Palaemonidae). Biol. Bull. 134:235-244.

S. pacifica, restricted to FW has a blood chloride level of ∿185 meq/l. Blood chloride level rises in brackish water, becomes isotonic with medium at ∿290 meq/l, and remains isotonic at still higher salinities. At final chlorinity of 510 meq/l (95% SW), *Syncaris* showed slight hypotonicity to medium, equivalent to approx. 0.1% NaCl. Total osmotic pressure of blood and urine show that hyper-regulation is maintained by *Syncaris* below 50% SW and that antennal gland plays a role in osmo-regulation by producing urine hypotonic to blood. With increasing salinity between 10 and 30% SW blood concentration rises and urine rapidly becomes isosmotic with blood. Maximum rate of change of urine concentration occurs at 30-50% SW. In 50% SW, urine and blood are isosmotic at ∿125% medium concentration. In 70% SW, urine, blood and environment are in equilibrium. *Palaemon macrodactylus* (Palaemonidae) is a strong regulator over the range 2-150% SW, and inhabits a wide range of salinities. Hyper-regulation occurs below 60% SW, and hypo-regulation in higher salinities.

1413. Boroughs, H., W.A. Chipman, T.R. Rice. 1957. Laboratory experiments on the uptake, accumulation, and loss of radionuclides by marine organisms. *In* Rept. Comm. Effects Atom. Radiation Ocean. Fish. U.S. Natl. Acad. Sci. Res. Coun. Publ. 551:80-87.

Uptake, accumulation and depuration studies were conducted with isotopes of Y, Sr, Cs, Zn and Ru with various species of marine teleosts, echinoderms, mollusks, crustaceans and algae. Sr-90 and Y-90 were accumulated by algae from solution in highly variable ratios when media contained both elements. Brine shrimp *Artemia salina*, shrimp *Panaeus setiferus*, blue crab *Callinectes sapidus*, clam *Venus mercenaria*, and bay scallop *Pecten irradians* rapidly accumulated Sr from seawater. In oyster *Crassostrea virginica*, Sr-89 accumulates mainly in shell; contaminated soft tissues depurate to 10% of previous radioactivity levels within 1 day. Oysters fed Sr-89-labelled *Carteria* cells reached steady state in 8 days. Most Sr-89 administered *per os* to skipjack tuna *Euthynnus yaito*, dolphin *Coryphaena hippurus*, and yellowfin tuna *Neothunnus macropterus* was eliminated rapidly. Gill, bone and integument were major accumulation sites. *Tilapia*, a sluggish bottom fish, excreted Sr-89 more slowly. Post-larval flounder took up Sr-89 more rapidly from seawater at 20 C than at 10 C. For Cs-137, the highest reported concentration factor (CF) for 3 families of algae was 3.1. CF's for Cs-137 were 6 after 20 d for *V. mercenaria* and 8 after 10 d for scallops. Various tissues of tuna were also examined for Cs uptake and depuration. Studies with *Nitzschia closterium* show algae rapidly take up Zn from seawater. After 2 hr exposure, Zn-65 CF's for scallop ranged from 0.8 for rectum to 82 for kidney, with an average soft tissue value of 20. Oysters concentrated Zn-65 up to 17,800x that in seawater. Croaker *Micropogon undulatus*, concentrate Zn-65 administered *per os* in liver and spleen, showing a slow turnover in skin, muscle and bone, and a rapid turnover in internal organs. *Nitzschia* studies show dividing plankton algae can take up large amounts of Ru-106. Particles of Ru-106 co-precipitated with $CaCO_3$ were ingested by sea urchin *Arabacia punctulata*, and bay scallop but radioactivity was not found in organs other than digestive tract. Menhaden *Brevoortia tyrannus*, did not incorporate Ru-106 from a $CaCO_3$ precipitate in water or from food sources into tissues to an appreciable extent.

1414. Boroughs, H. and D.F. Reid. 1958. The role of the blood in the transportation of strontium ^{90}-yttrium^{90} in teleost fish. Biol. Bull. 115(1):64-73.

Mixing time of Sr-90-Y-90 injected intraventrically into *Tilapia mossambica* is about 30 min. After 24 hrs, 0.8 to 1.6% of the injected dose remained in blood. Most Sr-90 in whole blood is plasma-borne; very little is found in cells or on cell walls. Y-90 is present in stroma. Pattern of internal distribution of intravascularly injected Sr-90-Y-90 is same as that found for either intramuscular or oral administration. Authors observed that vascularized tissues have a greater avidity for Y-90 than Sr-90.

1415. Boyden, C.R. 1974. Trace element content and body size in molluscs. Nature 251:311-314.

When trace element concentrations in shellfish are expressed on a weight-specific basis, highest values are often recorded in the smallest individuals. In those cases it is difficult to assess whether observed differences in element tissue concentrations between populations reflect real differences in environmental trace element constitution, or are due to variations in body size. This problem can be avoided by determining element concentrations over a range of body sizes and reference made to a specific size for comparative purposes.

In this account concentrations of Cd, Cu, Fe, Ni, Pb, and Zn were measured in individual molluscs over a wide size range. Six estuarine species were examined: limpet *Patella vulgata*, and *P. intermedia*; cockle, *Cerastoderma edule*; mussel, *Mytilus edulis*; and clam *Mercenaria mercenaria*, and *Venerupis decussata*. Total trace element content per individual Y relates to body weight W as a power function expressed by:

$$Y = aW^b \tag{1}$$

which on logarithmic transformation (base 10) yields a regression of the form:

$$\log Y = \log a - b \log W. \tag{2}$$

The weight specific relationship Y to body weight is essentially similar. Dividing (1) throughout by W yields:

$$Y' = Y/W - aW^b/W = aW^{b-1}. \tag{3}$$

Logarithmic transformation produces a linear function:

$$\text{Log } Y' = \log a + (b-1) \log W. \tag{4}$$

Clearly, equations (2) and (4) have related regression coefficients and share a common intercept (Y and Y´ = log a) when W = 1.0, log W = 0. The precise relationship between trace element content (μg) and dry body weight (g) differs depending on element and species. Three general relationships have been identified. First, element content is related to ∿0.75 power of body weight; this was evident for copper in all species examined; several other elements exhibited the same relationship. Second, element content is directly related to body weight (b ∿ 1.00). Nickel in all bivalve species examined and also Pb and Zn in M. mercenaria, Fe and Zn in V. decussata and Cd in M. edulis exhibited this relationship to body weight. In these cases, tissue element concentrations are independent of size. Third, element content is related to square of body weight (b ∿ 2.00). This pattern was only observed for Cd in limpet P. vulgata. Therefore in this case, element tissue concentration is directly proportional to body weight. Some earlier observations in the literature are consistent with the above relationships. A regression slope of 0.77 dictates that smaller individuals contain a higher concentration of metal than larger individuals. Such differences have been recognized for Pb in M. edulis, Zn in P. vulgata and Cu and Fe in M. mercenaria. The converse situation, with higher concentrations of Cd in large limpets compared with small individuals, has previously been reported for P. vulgata collected from the Severn Estuary. In the molluscs studied, however, it was usual for element concentrations to decrease or remain constant with increasing body weight.

In molluscs, absolute tissue element concentrations are related or determined by environmental concentrations. Within each species, however, different elements display different relationships to body weight. Regression coefficients related to body weight by a power of 0.77 implies a connection with metabolism, as many metabolic processes display a similar relation to body weight. The common regression coefficient of 0.77 is not significnatly different from 0.75 describing the relationship of respiration of poikilotherms to body weight, a value generally accepted to relate many metabolic functions to body weight. Thus in cases where an element is related to 0.77 body weight some aspect of metabolism could well be influencing final trace element content. Where the element content is directly related to body weight, as has been found for a variety of elements in several species, then a function of body weight such as the binding of specific compounds within tissues may play some role in determining total body element burden. But the absolute amount of metal is not dictated by the amount of such binding compounds within the tissues; certain metals such as cadmium and nickel in Mytilus, retain a specific slope relation of ∿1.00 between total body element content and body weight, even though absolute amount of metals within tissues differed by 12x for cadmium and 2x for nickel between two separate populations studied. A relation to square of body weight as shown by cadmium in limpets can best be explained as being due to removal of this element from body circulation and accumulation within specific tissues, possibly as a result of some exceptional affinity. The slope value of 2.00 in the limpet population examined may be due to the unusually elevated environmental cadmium concentration in the Severn Estuary. Populations of limpets from other areas, where environmental cadmium concentrations are lower, exhibit slopes between 1.3 and 1.5 suggesting that in this case, slope is variable and related to environmental cadmium concentration.

Knowledge of regression coefficients relating trace element content (or weight-specific concentration) to body weight is potentially a considerable aid in monitoring of metals within shellfish. Evidence is being gathered which suggests that in most cases regression coefficient relating element content to body weight remains constant regardless of season or environmental element concentration. The only case so far identified where slope differs between populations is that for cadmium in P. vulgata, though other exceptions may also be expected. If values of b are indeed constant for a particular element within a species, data pertaining to element content or concentration mean tissue weight for a sample of similar sized individuals may be substituted, together with the appropriate slope for element and species in question, into equations (2) or (4). The calculated intercept (log a) converted to real values may then be used for comparison between populations regardless of size of individuals sampled.

1416. Boyden, C.R. and M.G. Romeril. 1974. A trace metal problem in pond oyster culture. Marine Poll. Bull. 5:74-78.

Oysters Crassostrea gigas reared in power station cooling water at Hinkley Point on Severn Estuary, accumulated copper and zinc at levels up to 6,480 and 99,220 mg/kg dry wt, respectively. Cause of high Zn concentrations was attributed to corrosion of galvanized zinc trays upon which oysters were suspended. Increased copper levels were due to corrosion of phosphor bronze blades of recirculating pump. It is shown that considerable caution should be exercised with accessories used in rearing marine animals, particularly molluscs.

1417. Boyden, C.R., H. Watling and I. Thornton. 1975. Effect of zinc on the settlement of the oyster Crassostrea gigas. Marine Biology 31:227-234.

For late oyster larvae (21 to 26 days old), the LC-30 (5 day) value for zinc was 500 μg/l. Larval settlement was impaired by 125 μg Zn/l when compared to control (20-25 μg Zn/l). Exposure to this concentration of Zn immediately prior to settlement slowed behavioral development. However, larvae which settled in presence of Zn, when grown in clean water were as viable as controls. Zn at concentrations of 250 and 500 μg/l suppressed spat growth, but recovery was rapid in clean water conditions.

1418. Boyle, P.J. and E.J. Conway. 1941. Potassium accumulation in muscle and associated changes. Jour. Physiol. 100:1-63.

The study of K, Na and chloride changes in frog sartorii shows that K can be accumulated to upwards of 3x over normal levels. The significance of this and other changes observed are included in a general discussion of K concentration mechanisms in muscle.

1419. Bradley, H.C. 1904. The occurrence of zinc in certain invertebrates. Science 19(474):196-197.

Ashed hepatopancreas of *Sycotypus canaliculatus*, a marine gastropod, contained between 10.8 and 23.4% ZnO, 0.84% Fe, and approximately 8% Cu. Zinc was also found in blood of *Sycotypus* and ash of *Fulgur carica*. Zinc was not detected in other marine forms analyzed including the gastropod *Urosalpinx cinerea*, the bivalves *Mytilus edulis*, *Modiola plicatula*, *Argina pexata*, *Ostrea virginica*, and two species of decapod crustaceans.

1420. Braek, G.S., A. Jensen, and A. Mohus. 1976. Heavy metal tolerance of marine phytoplankton. III. Combined effects of copper and zinc ions on cultures of four common species. Jour. Exper. Mar. Biol. Ecol. 25:37-50.

Combined effects of Cu and Zn on growth of 3 species of marine diatoms and one dinoflagellate in culture were studied. Over a 10-day period, growth inhibition of *Amphidinium carteri* was observed at 50 µg/l of Cu^{2+} and 50 µg/l of Zn^{2+}; for *Thalassiosira pseudonana* this was 50 µg/l of Cu^{2+} and 400 µg/l of Zn^{2+}; for *Skeletonema costatum*, 75 µg/l Cu^{2+} and 100 µg/l Zn^{2+}; for *Phaeodactylum tricornutum*, 250 µg/l Cu^{2+} and 8000 µg/l Zn^{2+}. The two metals act synergistically to all algae except *P. tricornutum*. With this species an antagonistic effect was observed. Addition of zinc ions reduced inhibition of growth caused by the more toxic copper ions. Zinc toxicity to this alga increased at low concentrations of magnesium, indicating a common route for divalent metal ions in general.

1421. Brafield, A.E. and P. Matthiessen. 1976. Oxygen consumption by sticklebacks (*Gasterosteus aculeatus* L.) exposed to zinc. Jour. Fish Biol. 9:359-370.

During exposure to 1 mg/l Zn in calcium-free water, oxygen uptake by sticklebacks tends to rise followed by erratic values before declining as death approaches. Behavioral abnormalities such as increased ventilation rate, loss of balance, and long periods of inactivity alternating with spasmodic swimming also occur. Exposure to 6.5 mg/l Zn in high-Ca water causes a rise in oxygen consumption, followed by fluctuations in uptake rate, but without behavioral abnormalities. If restored to Zn-free water after 40 hr exposure to Zn, recovery is generally complete, although fluctuating rates of oxygen uptake persist.

1422. Brenko, M.H. and A. Calabrese. 1969. The combined effects of salinity and temperature on larvae of the mussel *Mytilus edulis*. Marine Biology 4:224-226.

Survival of larvae at salinities from 15 to 40^{o}/oo is uniformly good (70% +) at temperatures from 5 to 20 C, but is reduced drastically at 25 C, particularly at high (40^{o}/oo) and low (20^{o}/oo) salinities. Larval growth decreases at 25 C and also at 10 C with decline most pronounced at high and low salinities.

1423. Brenner, F.J., S. Corbett and R. Shertzer. 1976. Effect of ferric hydroxide suspension on blood chemistry in the common shiner, *Notropus cornutus*. Trans. Amer. Fish. Soc. 105:450-455.

Shiners were exposed to 3 mg/l ferric hydroxide for periods from two to eight weeks. Serum protein as separated by electrophoresis was divided into three major groups: 1 (bands 1-2); 2 (bands 3-5); and 3 (band 6). Group 1 proteins comprised about 55% of total serum protein in fish not exposed to ferric hydroxide. Serum proteins in groups 1 and 2 fractions decreased significantly, after a two-week exposure while group 3 fraction increased significantly to approx. 44% of total protein fraction compared with 20% in controls. After 4-week exposure to ferric hydroxide, group 1 fraction replaced group 3 as most prevalent, comprising 43% of total. All three protein groups increased following a 6-week exposure with fractional counts not significantly different from controls. After exposure for 8 weeks to ferric hydroxide, protein fractions decreased with all three fractions significantly less than controls. Blood sugar decreased from approx. 85 to 8 mg glucose/100 ml after a 2-week exposure and remained unchanged for next two weeks. In weeks 4 to 6, blood sugar level increased to approx. 65 mg glucose/100 ml, but was still significantly less than controls at approx. 85 mg glucose/100 ml. Serum potassium decreased from 2.2 to 1.9 m moles/l, while sodium ions increased from 1.2 to 1.5 m moles/l after a 2-week exposure to ferric hydroxide. After 4-week exposure, K increased to 2.3 m moles/l while Na ions decreased to 1.2 m moles/l; K concentration remained significantly greater than controls for remainder of study while Na content approximated control values.

1424. Briese, L.A., C.T. Garten, Jr. and R. R. Sharitz. 1975. Distribution of radiocesium in vegetation along a contaminated stream. *In*: Howell, F.G., J.B. Gentry and M.H. Smith (eds.). Mineral Cycling in Southeastern Ecosystems. U.S. Energy Res. Dev. Admin.: 509-517. Available as CONF-740513 from NTIS, U.S. Dept. Comm., Springfield, VA 22161.

Leaves of arrowhead *Sagittaria latifolia*, black willow *Salix nigra*, smartweed *Polygonum punctatum*, and woolgrass *Scirpus cyperinus* at 8 sites along a 20-km stream contaminated by radioactive effluent from nuclear production reactors contained mean levels of 488, 303, 192 and 86 n Ci Cs/kg dry wt, respectively. Cs-134-137 distribution in vegetation was species specific and independent of distance from entry point of effluent into stream, but concentrations were generally higher in plants where streamflow rates decreased. At all sites, Cs-134-137 in leaves were log normally distributed. Mean Cs-134-137 concentrations were linearly related to variance for all species, but slope and intercept values were species dependent.

1425. Bringmann, G. and R. Kuhn. 1959. Vergleichende wassertoxikologische Untersuchungen an Bakterien, Algen und Kleinkrebsen. Gesundheits-Ingenieur 80:115-120. (In German)

The following concentrations of metals salts, in mg metal per liter, began to show toxic effects upon the bacteria *Escherichia*: Ag 0.04, Cu 0.08, Cd 0.15, Ni 0.1, Hg 0.2, La 0.4, Cr 0.7, Ce 0.75 to 1.5, Th 0.8, Pb 1.3, Zn 1.4 to 2.3, U 1.7 to 2.2, Co 2.5, Sb 33, Se 90, W 167, and As 290. Toxic effects upon the algae *Scenedesmus* sp. were first evident at the following concentrations, in mg metal/l: Hg 0.03, Ag 0.05, Cd 0.1, Ce 0.14, La 0.15, Ce 0.15 to 0.2, Cu 0.15, Th 0.4 to 0.8, Cr 0.7, Ni 0.9 to 1.5, Co 1.0, Zn 1.0 to 1.4, Al 1.5 to 2.0, Ti 2.0, U 2.2, Pb 2.5, Se 2.5, Sb 3.5, Cr 4 to 6, Rb 14, Ba 34, As 35-46, Mo 54 and W 110. For the freshwater crustacean *Daphnia* sp., toxic effects were first observed at the following concentrations in mg/l: Hg 0.02 to 0.03, Ag 0.03, Cd 0.1, Cu 0.1, Cr 0.7, Zn 1.8, Se 2.5, As 4.6, Ti 4.6, Pb 5.0, Co 5.0, Ni 6.0, Sb 9.0, U 13, Li 16, Cr 42, Mn 50, La 160, Ba 170, Sr 210, and W 350.

1426. Brock, T.D. and J. Gustafson. 1976. Ferric iron reduction by sulfur- and iron-oxidizing bacteria. Appl. Environ. Microb. 32:567-571.

Acidophilic bacteria of the genera *Thiobacillus* and *Sulfolobus* can reduce ferric iron when growing on elemental sulfur as an energy source. It has been thought previously that ferric iron serves as a nonbiological oxidant in formation of acid mine drainage and in leaching of ores, but results suggest that bacterial catalysis may play a significant role in reactivity of ferric iron.

1427. Brooks, R.R., J.R. Lewis and R.D. Reeves. 1976. Mercury and other heavy metals in trout of central North Island, New Zealand. New Zealand Jour. Mar. Freshwater Res. 10(2):233-244.

Respective mean mercury, cadmium, copper, iron, manganese and zinc levels, in mg/kg wet wt, of trout from Lake Taupo, New Zealand, were 0.19 (Hg), 0.06 (Cd), 1.0 (Cu), 30.0 (Fe), 0.36 (Mn) and 7.9 (Zn) for flesh; 0.12, 0.15, 0.48, 72.0, 2.5 and 100.0 for gills; 0.16, 0.06, 5.5, 76.0, 1.5 and 51.0 for gonads; n.d., 0.12, 4.1, 115.0, 0.57 and 24.0 for heart; 0.53, 0.10, 2.4, 291.0, 0.83 and 30.0 for kidney; 0.35, 0.07, 184.0, 413.0, 1.2 and 34.0 for liver; and 0.36 (Hg), 0.11 (Cd), 2.1 (Cu), 1090.0 (Fe), 0.65 (Mn) and 27.0 (Zn) for spleen.

In trout from 17 other New Zealand lakes, flesh metal levels, in mg/kg wet wt, ranged from 0.34 to 2.7 for Cu, 8.0 to 46.0 for Fe, 0.32 to 1.0 for Mn, and 7.6 to 18.0 for Zn. Hg levels ranged from 0.22 to 2.8 mg/kg wet wt, in some cases exceeding the accepted maximum of 0.5 mg/kg wet wt.

1428. Brown, B. and M. Ahsanullah. 1971. Effect of heavy metals on mortality and growth. Marine Poll. Bull. 2:182-187.

LC-50's and sublethal effects on growth of Hg, Cu, Zn, Cd, Fe, and Pb on the polychaete Ophryotrocha labronica, and the brine shrimp Artemia salina, were determined. At a metal concentration of 1.0 mg/l, the time in hours to LC-50 for adult Ophryotrocha was 0.5 in Hg, 4.5 in Cu, 13.0 in Zn, 410 in Cd, 500 in Fe, and over 600 in Pb. For adult Artemia, these times were 25 for Hg, 168 for Cu, 240 for Cd, 300 for Fe, 312 for Zn, and 576 for Pb. Artemia larvae were more susceptible to solutions of Cu and Zn than adults, reaching LC-50 after 110 h in 1.0 mg/l Cu and 150 h in 1.0 mg/l Zn. Artemia showed no significant suppression of growth in copper (at 1.0 mg/l), but reduced growth was obtained with Zn and Pb at concentrations of 10, 5, 2.5, and 1.0 mg/l Zn and 10 and 5 mg/l Pb. Ophryotrocha showed growth inhibition at Cu concentrations of 0.1 and 0.05 mg/l; none was obtained in 0.1 mg/l Zn or 10 mg/l Pb.

1429. Brown, B.E. 1976. Observations on the tolerance of the isopod Asellus meridianus Rac. to copper and lead. Water Research 10:555-559.

Isopods from sites receiving mine-drainage in the rivers Hayle and Gannel in Cornwall have been shown by toxicity tests and growth rate experiments to be particularly tolerant to Cu and Pb. Animals from the Hayle where Cu water concentrations ranged from 0.01 to 0.1 mg/l and Cu sediment concentrations ranged from 126 to 2398 mg/kg but Pb concentrations were only <0.1 in water and 112 to 258 in sediments, are tolerant to both Cu and Pb. LC-50 (48 hr) values for Cu ranged from 1.65 to 2.50 mg/l and from 1.00 to 2.80 mg/l for lead. Animals from the River Gannel, with water Cu of 0.04 mg/l, sediment Cu of 1964 mg/kg and Pb concentrations of 0.19 and 6614 mg/l in water and sediments, respectively, are markedly tolerant to Pb. The LC-50 (48 hr) value for Pb was 3.50 mg/l; for Cu 1.90 mg/l. Copper concentrations of A. meridianus collected from the Hayle ranged from 67 to 304 mg/kg dry wt and 89 mg/kg dry wt for those found in River Gannel. Only specimens collected from River Gannel showed significant traces of Pb at 446 mg/kg dry wt. Tolerance to lead was shown to persist in animals from the Gannel F_2 generation which had been cultured in the laboratory.

1430. Brown, V.M., T.L. Shaw, and D.G. Shurben. 1974. Aspects of water quality and the toxicity of copper to rainbow trout. Water Research 8:797-803.

Effects of sewage effluent, an amino acid, humic substances and suspended organic matter on acute toxicity of water containing copper sulphate to trout Salmo gairdnerii was determined. In all cases toxicity of a given total concentration of copper was quantitatively reduced. Median periods of survival of rainbow trout in percolating filter effluent in presence of 2.0 mg Cu/l was raised from 8 hours in no effluent, to 26 hrs in 50% effluent and 80 hrs in 100% effluent. Glycine raised the 72 hr LC-50's of total Cu from 0.67 mg Cu/l in 0.25 mg glycine/l, to 1.4 mg Cu/l in 2 mg glycine/l, and to 4.7 mg Cu/l in 10 mg glycine/l. Median periods of survival of trout in 2.0 mg Cu/l and humic substances was raised from 470 min in no humic substances to 760 min in 1.5 mg humic substances/l, to 1050 min in 4.5 mg humic substances/l. The importance of suspended organic matter was shown when in its presence 70% of added copper was removed within 1 to 2 hrs whereas some 70 to 80% of added copper remained in solution in absence of organic solids. Authors concluded that data from toxicity tests with Cu in which natural surface waters are used for dilution purposes cannot define true toxicity for Cu or have application to other natural waters except when concentrations of toxic chemical species are known.

1431. Brown, V.M., D.G. Shurben and D. Shaw. 1970. Studies on water quality and the absence of fish from some polluted English rivers. Water Research 4:363-382.

Acute toxicity to rainbow trout, brown trout and dace was determined of water from rivers and an estuary contaminated by Zn, Cu and other pollutants. LC-50 (48 hr) concentrations of these waters diluted with clean water were 65% of those predicted from chemical qualities of the waters.

1432. Brungs, W.A., J.R. Geckler, and M. Gast. 1973. Acute and chronic toxicity of copper to the fathead minnow in a surface water of variable quality. Water Research 10:37-43.

Acute and chronic toxicity tests were conducted with fathead minnow Pimephales promelas, and copper. The source of dilution water was a natural stream to which a sewage treatment plant upstream contributed a variety of materials known to affect copper toxicity. Nominal total copper LC-50 (96 hr) values, determined with static testing procedures, ranged from 1.6 to 21 mg/l. Dissolved copper LC-50 (96 hr) values ranged from 0.60 to 0.98 mg/l. The maximum acceptable toxicant concentration based on survival, growth, reproduction, and hatchability of eggs, was between 0.066 and 0.118 mg/l.

1433. Brunker, R.L. and T.L. Bott. 1974. Reduction of mercury to the elemental state by a yeast. Appl. Microbiol. 27:870-873.

Cryptococcus isolated from a stream was capable of reducing mercury to the elemental state. This organism grows in Wickerham broth supplemented with high concentrations of mercury (II) chloride (180 mg of mercury per liter) and will metabolize (^{14}C) glucose in this medium as do cells in absence of mercury. Mercury was associated with cell wall and membrane, and in vacuoles within cytoplasm.

1434. Bryan, G.W. 1966. The metabolism of Zn and ^{65}Zn in crabs, lobsters and freshwater crayfish. In: Radioecological Concentration Processes. Proc. Inter. Symp., Stockholm, Apr. 25-29. Sym. Pub. Division, Pergamon Press, New York: 1005-1016.

Tissue zinc content in shore crab Carcinus maenas, lobster Homarus vulgaris, and freshwater crayfish Austropotamobius pallipes pallipes, was determined in seawater containing about 5 ug/l Zn. Whole body concentrations were 24, 22, and 24 mg/kg fresh weight, respectively. Hepatopancreas, with 56, 34, and 92 mg/kg Zn, respectively, and leg muscle, with 44 and 64 mg/kg Zn for crab and lobster, respectively, contained the highest levels. Distribution of Zn differed between tissues of the three species.

When placed in 25 ug/l and 100 ug/l Zn seawater (far from toxic levels), the crab maintained a comparatively constant Zn content so that the potential equilibrium concentration factor for Zn-65 is almost inversely proportional to the seawater Zn content (i.e. CF ∿3400 when seawater Zn = 7.3 ug/l and CF ∿270 when seawater Zn = 100-115 ug/l). By processes which involve Zn binding by blood, plus possible facilitated uptake in low Zn seawater, Zn-65 can be absorbed directly from seawater across the body surface (gills). Turnover of Zn is more rapid in high Zn seawater and consequently in high Zn seawater, Zn-65 reaches lower equilibrium concentration factors more rapidly, and is lost more rapidly. Absorption of Zn-65 and Zn from food is a comparatively rapid and complete process and is likely to be a more important route for uptake of radiozinc than direct absorption from seawater. Also, absorption of stable Zn from food increases the rate of loss of Zn and Zn-65 across the body surface and causes further losses to occur in faeces and urine. The lobster is generally very similar except that Zn loss in urine tends to take the place of loss across the body surface. The impermeability of freshwater crayfish eliminates Zn-65 absorption and loss across body surface. Therefore, apart from contamination of body surface due to adsorption, Zn-65 must all be absorbed from food. Hepatopancreas absorbs Zn and Zn-65 from food in stomach and regulates body Zn content. Removal of Zn and Zn-65 occurs in faeces and cannot be continued unless food is eaten and faeces produced.

1435. Bryan, G.W. 1967. Zinc concentrations of fast and slow contracting muscles in the lobster. Nature 213:1043-1044.

Various slow muscles from lobster Homarus vulgaris, contained 93, 101, and 105 mg Zn/kg tissue, which was 5 to 7 times more Zn than fast muscles (13, 15, and 20 mg/kg), and twice as much Zn as any other lobster tissue. Muscle/blood ratios for Zn-65 in slow muscle are roughly double those for fast muscle which implies that slow muscle is more permeable to Zn. Author suggests that the differences between muscle-types may be related to differences in enzyme content.

1436. Bryan, G.W. 1974. Adaptation of an estuarine polychaete to sediments containing high concentrations of heavy metals. In: Vernberg, F.J. and W.B. Vernberg (eds.). Pollution and Physiology of Marine Organisms. Academic Press, New York: 123-135.

Populations of Nereis diversicolor from metal-polluted estuaries were more tolerant to metals than populations from lower metal content environments in S.W. England. For Cu, Cd, Pb, and Ag, body concentration was directly proportional to that of sediment.

Populations from high metal environments had 96-hr LC-50's of 2.3 mg Cu/l and 94 mg Zn/l. Polychaetes from low metal sediments had 96-hr LC-50's of 0.54 Cu/l and 55 mg Zn/l. Tolerance to Cu, and possibly Ag and As, appears to depend on a better detoxification system. Zn tolerance is due to decreased body surface permeability.

1437. Bryan, G.W., A. Preston and W.L. Templeton. 1966. Accumulation of radionuclides by aquatic organisms of economic importance in the United Kingdom. In: Proc. Symp. on the Disposal of Radioactive Waste into the Seas, Oceans, and Surface Waters. Int. Atom. Ener. Agen., Vienna: 623-637.

Extent to which radionuclides and stable isotopes of Cs, Sr, Ru, Ce, Zr, Nb, Mn, Co, and Zn can be accumulated by edible plants, molluscs, crustaceans and fish in sea and fresh water was conducted in the United Kingdom. Results from laboratory experiments on rates of uptake and factors affecting them have been combined with results from field work at Windscale, from fallout studies and from stable isotope analyses. Cs:K and Sr:Ca concentration factor ratios are also examined.

1438. Bryan, G.W. and E. Ward. 1962. Potassium metabolism and the accumulation of ^{137}caesium by decapod crustacea. Jour. Mar. Biol. Assn. U.K. 42(2):199-241.

In starved lobsters Homarus vulgaris, and prawns Palaemon serratus, Cs-137 is taken up and lost far more slowly than K-42. Although all inactive K in animals can be exchanged with K-42, higher Cs-137 concentration factors of 8 for lobsters and 25 for prawns were reached because both species have higher plasma/medium ratios for Cs-137 than K at equilibrium despite selective Cs-137 excretion. Except for hepatopancreas in lobsters and fed prawns, all soft tissues can probably attain higher tissue/plasma ratios for Cs-137 than inactive K. In freshwater crayfish Austropotamobius pallipes pallipes, in 0.1% seawater, concentration factors of 50-200 and 4500 were obtained for Cs-137 and K, respectively. Crayfish selectively excrete Cs-137 in urine relative to K at a lower concentration than in plasma. Muscle is the principal limiting factor in uptake and loss of Cs-137 by all species, but body surface is limiting to K-42 exchange. Authors suggest that for prawns in a constant environment, feeding is probably less important than uptake over body surface; but in crayfish,feeding is probably more important.

1439. Buhler, D.R., R.R. Claeys and B.R. Mate. 1975. Heavy metal and chlorinated hydrocarbon residues in California sea lions

(Zalophus californianus californianus). Jour. Fish. Res. Bd. Canada 32:2391-2397.

Healthy sea lions collected from the central Oregon coast in 1971 had total mercury (% methylmercury) values, in mg/kg wet wt of 74 (3.7%) in liver, 6.9 (17.2%) in kidney, 1.2 (88.6%) in muscle, 0.6 (88.1%) in heart, 0.5 (59.4%) in cerebellum, 0.4 in cerebrum, and 0.2 in fat. Sick animals (apparently with leptospirosis) collected in 1970 and 1971 had similar Hg levels except in liver (161 mg/kg) and muscle (1.6 mg/kg).

Respective tissue cadmium levels, in mg/kg wet wt, of healthy sea lions collected during 1971 and 1973, and sick animals collected during 1970 and 1971, were 2.0 and 2.6 for liver, 10.2 and 10.1 for kidney, 0.13 and 0.07 for muscle, 0.14 and n.d. for heart, 0.05 and 0.06 for cerebellum, 0.04 and 0.17 for cerebrum, and 0.04 and n.d. for fat. Although Hg and Cd levels in tissues of some sick sea lions were significantly higher than those present in healthy animals, authors conclude that it is not possible to relate these differences to onset of leptospirosis.

1440. Buikema, A.L., Jr., J. Cairns, Jr. and G.W. Sullivan. 1974. Evaluation of Philodina acuticornis (Rotifera) as a bioassay organism for heavy metals. Water Resources Bull. 10:648-661.

After 96 hrs in soft water, effective concentrations causing 50% immobilization (EC-50) of various metal salts to the rotifer P. acuticornis, in mg/l, were: Cd 0.2 (as sulfate) and 0.5 (as chloride), Cu 0.6, Hg 0.8, Zn 1.2 (as sulfate) and 1.5 (as chloride), Ag 1.4, Ni 2.9 (as chloride), Cr 3.1, Ni 7.4 (as sulfate), Pb 50.4, and Co 59.0. The 96 hr EC-50 values in hard water were: Cd 0.3 mg/l, Cu 1.1, Hg 2.1, Cr 15.0 and Pb >150. Cadmium sulfate and zinc sulfate were more toxic than their chloride forms in soft water after 96 hrs, while the opposite was true for nickel. Increased water hardness decreased the toxicity of metals tested. Results suggest that P. acuticornis may be more sensitive than bluegill sunfish to Cd, Cu, Ni, Zn and Cr but less sensitive to Pb. P. acuticornis was also tested for exposure to ammonium chloride and phenol and was found to be extremely tolerant to both. The feasibility and economics of using P. acuticornis as a bioassay organism were discussed.

1441. Burkett, R.D. 1975. Uptake and release of methylmercury-203 by Cladophora glomerata. Jour. Phycol. 11:55-59.

C. glomerata, a freshwater alga, was exposed to 10, 50, or 100 ug CH_3 Hg-203Cl/l. Formalin-killed alga was exposed to a concentration of 50 ug CH_3 Hg-203Cl/1. Uptake was monitored for 16 days, after which Cladophora was placed in uncontaminated water and release of CH_3 Hg-203 monitored for up to 16 days. Sorption occurred at all concentrations; live algae accumulated more methylmercury than formalin-killed algae. Accumulation by live Cladophora peaked at 2 days for all exposure concentrations, suggesting that uptake rate was independent of CH_3 Hg-203 concentration. A maximum concentration factor of 5597 was obtained for exposure to 50 ug CH_3 Hg-203/1 for 24 hrs. Desorption was nominal during 16-day release period. Mechanisms of CH_3 Hg-203 uptake by Cladophora are discussed.

1442. Burovina, I.V., V.V. Glazunov, V.G. Leont'yev, V.P. Nesterov, I.A. Skul'skiy, D.G. Fleyshman and M.N. Shmitko. 1963. Lithium, sodium, potassium, rubidium and cesium in the muscles of marine organisms of the Barents and Black Seas. Doklady Akad. Nauk SSSR 149:170-172.

Ratios of concentration of selected elements in 100 g of fresh muscle tissue to those in 100 ml of seawater were determined for various species of coelenterates, annelids, molluscs, crustaceans and echinoderms. Ratios were as follows: Li, 0.52; Na, 0.30; K, 8.7; Rb, 11.0; and Cs, 5.8. Similar ratios for fish and elsamobranchs were: Li, 0.36; Na, 0.12; K, 15.2; Rb, 19.6; and Cs, 8.4.

1443. Burton, J.D. and T.M. Leatherland. 1971. Mercury in a coastal marine environment. Nature 231:440-442.

Clams Mercenaria mercenaria, from Southampton Water, England, contained 0.18 to 0.57 mg mercury/kg dry flesh wt (0.03 to 0.12 mg/kg wet wt). Values reported for various molluscs, including Mercenaria, collected off the coasts of North America are in the higher but overlapping range of 0.4 to 21 mg Hg/kg dry wt.

1444. Burton, R.F. 1975. A method of narcotizing snails (Helix pomatia) and cannulating the haemocoel and its application to a study of the role of calcium in the regulation of acid-base balance. Comp. Biochem. Physiol. 52A:483-485.

Exposure of snails to 10% CO_2 caused haemolymph concentrations of HCO_3 and Ca to increase up to 1220 and 520 mg/1 in 4 hours but Na and Mg levels were not measurably affected. Results indicate that HCO_3 and Ca are in a 2:1 ratio in the haemolymph. Infusion of $NaHCO_3$ led to subsequent loss of HCO_3 and Ca from the haemolymph in more than 2:1 ratio. Infusion of $CaCl_2$ led to subsequent loss of HCO_3 and Ca in a ratio of 2:1 or less. This indicates that other unidentified ions are involved in response to CO_2.

1445. Butterworth, J., P. Lester, and G. Nickless. 1972. Distribution of heavy metals in the Severn Estuary. Marine Poll. Bull. 3(5):72-74.

Concentrations of zinc, cadmium, and lead in water, sediments, seaweeds, and shore animals were determined at numerous locations on the southern shore of the estuary. Abnormally high levels of the metals were transmitted to living material, with particularly high concentrations accumulated in the dog whelk, Thais. Highest concentrations, consistently found in the upper estuary, in mg/kg, are given for Zn, Cd, and Pb, respectively: Fucus vesiculosus 800, 220, 8.5; Littorina littorea 520, 210, 3.0; Patella vulgata 580, 550, 9.5; Thais lapillus 3100, 425, 27.0; sediment 590, 4.7, 200; and seawater (in ug/l) 52, 5.8, 2.5. Contamination was detectable 144 km downstream of the most heavily-impacted area.

1446. Buyanov, N.I. and T.M. Antonenko. 1975. Cesium-137 concentration hydrobionts, water and substrate of bodies of water with a different mineral composition. Jour. Ichthyology 15(1): 159-163.

Comparison of Cs-137 content from a mineral-poor reservoir (K content 0.6 mg/l) with a mineral-rich reservoir (K content 20 mg/l) showed that Cs-137 content in fishes is inversely related to K content. In the mineral-poor reservoir Cs-137 content, in 10^{-12} Ci/kg, was: 0.6 in water, 280 in zooplankton, 380 in cisco Coregonus albula, 1320 in perch Perca fluviatilus, and 1220 in pike Esox lucius. Cs-137 concentrations in the mineral-rich reservoir were: 0.2 in water, 1 in phytoplankton, 40 in zooplankton, 10 in the mollusk Dreissena polymorpha, 10 in roach (teleost) Rutilus rutilus, 18 in perch and 13 in pike. Authors suggest that food chain dynamics may indirectly affect entry of radioisotopes into fish.

1447. Caines, L.A. and A.V. Holden. 1976. Stream pollution by an organomercury compound. Bull. Environ. Contamin. Toxicol. 16:383-391.

Industrial treatment of seed potatoes with methoxyethylmercuric chloride occurs during a 10-week period in autumn. One result is that sediment Hg levels in a small stream increased from 6 mg/kg in August to 100 mg/kg in October at the outfall point. The submerged macrophyte Callitriche sp. showed an increase in mercury from 1 mg/kg dry wt to 2215 mg/kg dry wt during this period. The emergent *Myosotis* sp. reached 300 mg Hg/kg dry wt in October compared to less than 1 mg/kg dry wt in August. Trout *Salmo trutta*, and grayling *Thymallus thymallus*, caught upstream from the outfall had Hg muscle concentrations of less than 0.1 mg/kg wet wt. However, at the outfall point, trout and grayling had Hg muscle concentrations of up to 20 and 12 mg/kg wet wt, respectively. Following adoption of a revised waste treatment program in 1973, few fish exceeded 0.5 mg/kg wet wt; in 1974, none exceeded 0.4 mg/kg wet wt.

1448. Cairns, J., Jr., A.G. Heath and B.C. Parker. 1975. The effects of temperature upon the toxicity of chemicals to aquatic organisms. Hydrobiologia 47(1):135-171.

The literature on temperature impact on toxicity of zinc, cadmium, copper, chromium, and mercury salts as well as other compounds to fish, algae, bacteria, protozoa, mollusca, and crustacea is reviewed.

1449. Cairns, J., Jr., G.R. Lanza and B.C. Parker. 1972. Pollution related structural and functional changes in aquatic communities with emphasis on fresh water algae and protozoa. Proc. Acad. Nat. Sci. Philadelphia 124(5):79-127.

Use of microbial communities for monitoring pollution in aquatic environments is proposed. Past approaches, including "target species" and "saprobian system" techniques are reviewed. Characteristics of algal and protozoan community structure and function are discussed. Importance of environmental parameters, such as organic pollution, availability of nutrients, temperature and presence of toxic substances, including halogens, pesticides, surfactants, oils, suspended solids, reducing agents, radioactive wastes and metals in influencing species composition are discussed in terms of previous work. Literature reviewed includes effects of Zn, Cu, Cd, Li, Cr, Hg, Ni, Pb, Ca, Mg, Fe on aquatic fungi, bacteria, algae, protozoa and fish.

1450. Cairns, J., Jr., and D. Messenger. 1974. An interim report on the effects of prior exposure to sublethal concentrations of toxicants upon the tolerance of snails to thermal shock. Arch. Hydrobiol. 74(4):441-447.

The possibility that freshwater snails suffer higher mortality rates from rapid heat shock if previously subjected to sublethal concentrations of Zn, Cr, and phenol was investigated. Forty-eight hr LC-50's for Cr^{+3} and Zn^{+2} (in mg/1), respectively, for *Goniobasis livescens* were 2.4 and 7.7, for *Lymnaea emarginata* 42.0 and 4.1, for

Physa integra 0.4 and 4.4, and Zn^{+} only for *Helisoma anceps* 5.2. Sublethal concentrations tested were 0.2x these values. In heat-shock experiments *G. livescens* had mean mortality rates 12 to 60% higher when previously exposed to toxicants. Authors conclude that prior or concomitant exposure to toxic chemicals may decrease tolerance to increased temperature; however, responses are species and chemical specific, with no general pattern evident.

1451. Cairns, J., Jr., W.H. van der Schalie and G.F. Westlake. 1975. The effects of lapsed time since feeding upon the toxicity of zinc to fish. Bull. Environ. Contamin. Toxicol. 13(3): 269-274.

Groups of 10 goldfish were placed into 18 l of water containing a lethal concentration (100 mg/l) of zinc as ZnSO$_4$ at 0, 1, 2, 4, 6, 12, 24, and 72 hours after feeding. Time until death was recorded for individual fish. Statistical analysis revealed a slight but non-significant increase in survival time as the interval between feeding and exposure to zinc increased. These variations in survival time are not of sufficient magnitude to support the standard acute bioassay requirement that fish not be fed for 24 or 48 hours prior to exposure to a toxicant.

1452. Calabrese, A. 1969. Individual and combined effects of salinity and temperature of embryos and larvae of the coot clam, *Mulinia lateralis* (Say.). Biol. Bull. 137:417-428.

Embryos of *M. lateralis* held at 25 C developed satisfactorily (70% or more of maximum) within salinity range of 22.5 to 30^{o}/oo; 27.5^{o}/oo was optimum. Ten percent of embryos survived at salinities as low as 15^{o}/oo and 1.2% as high as 37.5^{o}/oo. Some larvae survived at all salinities tested (7.5 to 37.5^{o}/oo) with 70% or more survival within the range of 20 to 27.5^{o}/oo, and an optimum of 25^{o}/oo. Salinity tolerance range of embryos narrowed above and below 22.5 C. Survival of larvae was relatively uniform at temperatures of 7.5 to 27.5 C and at salinities from 10 to 35^{o}/oo. Growth of larvae was most rapid in the salinity range 20 to 35^{o}/oo and temperature range 22.5 to 27.5 C.

1453. Calabrese, A., F.P. Thurberg, M.A. Dawson and D.R. Wenzloff. 1975. Sublethal physiological stress induced by cadmium and mercury in winter flounder, *Pseudopleuronectes americanus*. *In:* Koeman, J.H. and J.J.T.W.A. Strik (eds.). *Sublethal effects of toxic chemicals on aquatic animals*. Elsevier Sci. Pub. Co., Amsterdam: 15-21.

After 60 days exposure to 0.005 and 0.010 mg/l cadmium, flounder gill-tissue oxygen consumption was reduced from about 675 to 590 µl/hr/g. Fish exposed to 0.010 mg/l mercury increased respiration from 560 to 640 µl/hr g, while fish exposed to 0.005 mg/l Hg respired at same rate as controls. There was no significant difference between controls and cadmium-exposed fish for any hematological test, but significant differences were noted in mercury-exposed fish. Plasma protein rose from 5.4 to 6.3% in fish exposed to 0.005 mg/l Hg with a decrease in plasma osmolality; normally hyposmotic blood became even more so. Exposure to 0.010 mg/l Hg also resulted in a significant rise in plasma protein while hemocrit, hemoglobin and mean corpuscular hemoglobin decreased. Significant levels of Hg, but no detectable amounts (<0.2 to 0.3 mg/kg wet wt) of Cd were found in blood and gill tissues. Mean levels of 20.6 and 42.8 mg Hg/kg wet wt were present in gills of fish exposed to 0.005 and 0.010 mg/l Hg, respectively, as opposed to <0.14 in controls. Blood accumulated Hg significantly at 2.9 and 3.8 mg/kg wet wt for exposures of 0.005 and 0.010 mg/l. Mean Hg levels in blood of control flounder was <0.04 mg/kg wet wt.

1454. Carbonneau, M. and J.-L. Tremblay. 1972. Etude du role de *Scirpus americanus* Pers. dans la depollution des eaux contaminees par les metaux lourds. Naturaliste Canadien 99: 523-532.

Natural levels of mercury in the St. Lawrence River during August 1971 ranged from <0.04 to 0.11 µg/l; levels in rhizomes of *Scirpus americanus* contained more mercury (0.83 mg/kg) and lead (34.0 mg/kg) than stems (0.19 mg/kg Hg; 6 mg/kg for Pb) and suggested to authors that this plant can be utilized as a natural depolluting agent.

In laboratory studies on *Scirpus*, *Eleocharis smalli*, and *Bidens cernua* (other bog-like plants) with salts of Cd, Hg, and Pb, relatively high concentration factors were demonstrated in rhizomes. Initial concentrations of Pb in the water of 0.05 mg/l resulted in 336 mg/kg in *Scirpus* rhizomes; at 1.0 mg/l, levels of 376 and 1782 were observed in *Scirpus* and *Eleocharis* rhizomes, respectively; at 1.5 mg/l of Pb *Scirpus* contained 885, *Eleocharis* 3321, and *Bidens* 625 mg Pb/kg wet wt after 72 hrs (levels in stems were substantially lower). With inorganic mercury salts, initial concentrations in the media between 0.1 and 0.5 mg Hg/l produced levels in *Scirpus* rhizomes from about 75 to 350 mg Hg/kg wet wt in 72 hrs; for *Scirpus* stems, Hg values were lower at the same test concentrations, *viz* 8 to 42 mg/kg. Cd levels of 0.05, 0.1, and 0.4 mg/l in water produced Cd values in mg/kg wet wt of *Scirpus* rhizomes of 26, 129, and 238, respectively, in 72 hrs; maximum value reached in stems was 14 mg/kg.

1455. Cardiff, I.D. 1937. Observations with reference to arsenic on apples and other foodstuffs. Proc. Wash. State Horticulture Assn. 33:153-168.

Levels of As and Pb in various foods as determined from previous studies, in mg/kg, are: marine algae—*Chondrus* 61 As, *Laminaria* 110 As; shrimp 2 to 9 As and as high as 150 As; prawn 25 As, 147 Pb; lobsters 2 to 25 As, 22 to 82 Pb; cockles 14 As, 22 Pb; clams 1.2 to 2.2 As; scallops 25 As, 44 Pb; mussels 25 As, 93 Pb; oysters 1.2 to 2.0 As; haddock 4.8 As; tuna 0.6 As; codfish 2.2 As; cod liver oil (U.S.) 0.5 As; cod liver oil 0.6 to 1.1 As; and sardine oil 1.0 As.

1456. Carlisle, D.B. 1958. Niobium in ascidians. Nature 181:933.

Mussels *Mytilus edulis* contained 0.22 mg vanadium and <0.001 mg niobium per kg dry flesh. *Phallusia mammillata*, an ascidian, contained 1260 mg V and <0.001 mg Nb per kg dry wt. Respective average V and Nb contents in mg/kg dry wt of *Molgula manhattensis* another ascidian, were 16.0 and 1.9 in test, 101 and 56 in flesh without test, and 54.0 and 26.5 in whole organism. Individual *Molgula* contained either 29 to 98 mg V and <0.001 mg Nb per kg dry wt, or 25 to 75 mg Nb and <2 mg V per kg dry wt. If, as has been suggested, the V present in petroleum deposits is derived from ascidians, it seems likely that these may also be the source of the Nb which is also present on these deposits.

1457. Carlisle, D.B. 1968. Vanadium and other metals in ascidians. Proc. Roy. Soc. London B. 171:31-42.

Ascidian blood contains V, Nb, Ta, Ti, Cr, Mn, Fe, and possibly Zr, Mo and W. In the family Ascidiidae, V is the only heavy metal in blood; other families have two or more of those metals with V and Nb usually predominating. But the mixture of metals in ascidians may be dictated by availability in seawater. Metal-holding pigments are powerful reducers, and may assist in transport of molecular oxygen in Ascidiidae during times of low O_2 tension.

1458. Carpenter, K.E. 1930. Further researches on the action of metallic salts on fishes. Jour. Exp. Zool. 56(4):407-422.

In 0.2 to 0.0005 M solutions of lead nitrate or lead acetate, 13 species of freshwater teleosts formed Pb-mucous films over gills and body surfaces, causing respiratory distress, and death if sufficient Pb concentrations were present. In a multi-species collection of fish, susceptibility to soluble Pb was directly correlated with metabolic rate. In *Notropis cornutus* and *Hyborhynchus notatus*, body weight and temperature were inversely related to susceptibility and metabolism. Starvation for 4 to 5 weeks decreased both metabolic rate and susceptibility; subsequent starvation increased both. A certain minimum volume of solution was necessary to provide maximal lethal action for a constant concentration of $PbNO_3$. This volume increased for decreasing $PbNO_3$ concentrations. From studies of several fish in the same solution, and the replacement of one fish by another in the same solution, author suggests that critical volume for maximal lethal action is proportional to total weight of fish used. Survival times for *N. cornutus*, weighing 2.5 g, in 4 l of medium, were 42 minutes in 21 g Pb/l and 67 minutes in 5 g Pb/l.

1459. Cearley, J.E. and R.L. Coleman. 1974. Cadmium toxicity and bioconcentration in largemouth bass and bluegill. Bull. Environ. Contamin. Toxicol. 11:146-151.

A 6-month static bioassay, utilizing 0.85, 0.08, 0.008 and 0.0005 mg/l cadmium concentrations was conducted on bluegill *Lepomis macrochirus*, and bass *Micropterus salmoides*. Fifty-percent mortality was shown within 56 days by bass at 0.85 mg Cd/l; for 0.08 mg Cd/l the LC-50 was 82 days. Bass exposed to 0.008 mg Cd/l had 12½% mortality in the 6-month period. Fifty percent of the bluegills exposed to 0.85 mg Cd/l died within 138 days. Those exposed to 0.08 and 0.008 mg Cd/l survived the 6-month study. Bass appeared to be more sensitive than bluegill to Cd. The first abnormal behavior patterns of a toxic reaction occurred during the third week for bass exposed to 0.85 mg Cd/l, during the seventh week for 0.08 mg Cd/l and the twelfth week for 0.008 mg Cd/l; these behavior patterns, indicative of neurological damage were observed in bluegill during the thirteenth week of exposure at 0.85 mg Cd/l. Quantity of metal accumulated increased as exposure concentration increased. Equilibrium developed between concentrations of metal in water and in tissues after 2 months. Cadmium accumulations in bass tissues were higher in internal organs, followed by gills and remainder of body.

1460. Cedeno-Maldonado, A. and J.A. Swader. 1974. Studies on the mechanism of copper toxicity in *Chlorella*. Weed Sci. 22(5): 443-449.

In *Chlorella sorokiniana*, photosynthesis and respiration were inhibited within 2 to 5 min after addition of 64 mg Cu^{2+}/l. Cells incubated for a short time in concentrations of Cu^{2+} that completely inhibited photosynthesis were unable to grow when cultured in Cu-free medium, indicating destruction of photosynthetic apparatus and autotrophic growth ability. Dark preincubation, as well as high bicarbonate concentrations, decreased inhibition. Cu^{2+} reduced cellular chlorophyll and sulfhydryl content, but anaerobiosis, which increased toxicity, had little effect on sulfhydryl content.

1461. Cedeno-Maldonado, A., J.A. Swader and R.L. Heath. 1972. The cupric ion as an inhibitor of photosynthetic electron transport in isolated chloroplasts. Plant Physiol. 50:698-701.

Strong inhibition of uncoupled photosynthetic electron transport by Cu^{2+} in isolated spinach chloroplasts was observed by measuring changes in O_2 concentration in reaction medium. Inhibition was dependent not only on the concentration of Cu^{2+}, but also on the ratio of chlorophyll to Cu^{2+}. Binding of Cu^{2+} to chloroplast membranes resulted in removal of Cu^{2+} from solution. When chloroplasts were exposed to preincubation in light, there was increased inhibition as a result of Cu^{2+} binding to inhibitory sites. Preincubation in dark resulted in Cu^{2+} binding to noninhibitory sites and decreased inhibition. Degree of inhibition was lower at low light intensities than at high light intensities. Of the two photosystems examined, I was more resistant to inhibition than II. Oxidizing site of photosystem II was site most sensitive to Cu^{2+}.

1462. Chapman, A.C. 1926. On the presence of compounds of arsenic in marine crustaceans and shell fish. Analyst (London) 51: 548-563.

Edible seaweeds contained between 5 and 125 mg/kg of arsenic (as arsenious oxide on the air dry substance). British oysters contained 3-10 mg/kg wet wt but values for Portuguese oysters were higher (33-70 mg As per kg wet wt). Whole scallops contained 36-85 mg/kg wet wt; As content was practically uniform in all tissues examined. Ranges for mussels, cockles, whelks, and periwinkles, on a mg/kg wet wt basis, were 36-119, 17-40, 12-40, and 20-36, respectively. Lobster flesh contained between 18 and 110 mg As/kg wet wt; boiling for 20 minutes appears to have no effect upon As content of flesh. Prawns, Nephrops norvegicus, contained 36-80 mg/kg wet wt in flesh, but one pooled sample of two dozen was anomalously high (174 mg As/kg wet wt). Other crustaceans examined (crabs, shrimps, spiney lobster—Palinuris vulgaris) contained between 17 and 70 mg As/kg wet wt. Arsenic in seawater averaged 0.33 mg/l (range 0.14-1.0). Flounder-like fishes (plaice, sole, dab) contained between 3 and 10 mg As/kg wet wt; a sample of Russian caviar had 5 mg As/kg wet wt. Preliminary studies indicated that arsenic in lobster was present as a complex organic substance. Freshwater snails, crustaceans, and fishes were much lower in As than their marine counterparts (range 0.4-1.4 mg As/kg wet wt). Canned prawns, crayfish, and oysters ranged from 0.5-40 mg As/kg wet wt; crabs contained up to 85 mg/kg wet wt.

Limited studies with humans fed lobster showed large amounts of As excreted in the urine, the concentration being proportional to the amount of lobster ingested.

1463. Chau, Y.K., P.T.S. Wong, B.A. Silverberg, P.L. Luxon, and G.A. Bengert. 1976. Methylation of selenium in the aquatic environment. Science 192:1130-1131.

Conversion of inorganic and organic selenium compounds to volatile selenium compounds, such as dimethyl selenide, dimethyl diselenide, and an unknown compound, by microorganisms in lake sediments of the Sudbury area of Ontario, has been observed. This conversion could be effected by pure cultures of Aeromonas sp., Flavobacterium sp., Pseudomonas sp. and an unidentified fungus, all found in lake sediments exhibiting methylation. Production of volatile selenium was temperature dependent with 25% less $(CH_3)_2Se$ produced at incubation temperatures of 10 C as at 20 C; reduction was 90% at 4 C.

1464. Chave, K.E. 1954. Aspects of the biogeochemistry of magnesium. I. Calcareous marine organisms. Jour. Geology 62:266-283.

Percent $MgCO_3$ in calcareous parts of many species of marine organisms were determined. This ranged from 0.3 to 15.9% for foraminfera, 5.5 to 14.1% for sponges, 0.1 to 0.7% for madreporian corals, 6.0 to 13.8% for alcyonarian corals, 5.5 to 15.9% for echinoids, 2.0 to 10.2% for echinoid spines, 8.6 to 16.1% for asteroids, 9.2 to 16.5% for ophiuroids, 8.3 to 15.9% for crinoids, 6.4 to >16.5% for annelid worms, 0.09 to 2.8% for pelecypods, 0.08 to 2.4% for gastropods, 0.05 to 7.0% for cephalopods, 5.2 to 11.7% for decapod crustaceans, 2.0 to 10.2% for ostracod crustaceans, 1.35 to 4.6% for barnacles, and 7.7 to 28.7% for calcareous algae. Increased ambient water temperature resulted in greater % $MgCO_3$ in calcareous hard parts.

1465. Cherry, D.S., R.K. Guthrie, J.H. Rodgers, Jr., J. Cairns, Jr., and K.L. Dickson. 1976. Responses of mosquitofish (Gambusia affinis) to ash effluent and thermal stress. Trans. Amer. Fish. Soc. 105:686-694.

Gambusia was the only fish species inhabiting a drainage system that received high coal ash concentration at one end and thermal discharges at the other. Concentrations of 40 elements were determined in this aquatic system. The order for the most abundant elements in water was Fe > Al-Si > Ca > Na > K > Mg > Ti > Ba > Rb > Cu > Zn > Sr > Ce > Cr. The order of abundance and concentration in mg/kg wet wt, in mosquitofish was Ca 5,752; K 1,946; Na 309; Mg 307; Al-Si 215; Fe 154;

Sr 36; Ba 20; Ti 15; Zn 12; Rb 10; Mn 10; Se 9; and Cu 8. Relatively low levels of the following were present: Cd, Sn, Se, Mn, Sb, Co, As, W, V, Hg, Ta, Mo, Th, La, Cs, Yb, U, Hf, Sc, Sm, Au, Lu, and In. The most active ash removal mechanism was settling since 35 of the 40 elements were most highly concentrated in the sediment. Elements that underwent biological magnification were Se, Zn and Ca.

1466. Cherry, R.D., S.W. Fowler, T.M. Beasley, and M. Heyraud. 1975. Polonium-210: its vertical oceanic transport by zooplankton metabolic activity. Marine Chemistry 3:105-110.

Previous work has shown that Po-210 is removed from the upper mixed layer at a rapid rate, expressible by a turnover (or mean residence) time of 0.6 years. Since Po is known to be highly concentrated in numerous marine species, a method was devised to assess the importance of marine zooplankton in removing this radionuclide from the surface waters. Measurements of Po-210 losses from living zooplankton (euphasiids) lead to a rapid turnover time of the order of 0.9 years due to zooplankton metabolic activity alone. It is shown experimentally that fecal pellet deposition constitutes a major mechanism in transporting the radionuclide from surface to deeper waters.

1467. Chervinski, J. and E. Hering. 1973. Tilapia zilli (Gervais) (Pisces, Cichlidae) and its adaptability to various saline conditions. Aquaculture 2:23-29.

Maximum salinity tolerance of T. zilli on direct transfer is between 60-70% seawater (S=23.4 to 27.3^{o}/oo). Through gradual adaptation, the fish can withstand up to 100% seawater (S=39^{o}/oo). T. zilli collected from a hypersaline lagoon, and from a freshwater body showed differences in ratio of: head to standard length, depth to standard length, preorbital to standard length and interorbitol to standard length.

1468. Chervinski, J. and M. Zorn. 1973. Pampano, Trachinotus ovatus L. (Pisces, Carangidae) and its adaptability to various saline conditions. Aquaculture 2:241-244.

Laboratory experiments were conducted to determine the adaptability of pampano, a marine fish, to low salinities. The minimum salinity tolerated by juveniles on direct transfer is 7.8^{o}/oo. Through gradual adaptation pampano can withstand salinity as low as 1.5^{o}/oo.

1469. Childs, E.A. 1974. Functionality of fish muscle: emulsification capacity. Jour. Fish. Res. Bd. Canada 31:1142-1144.

Emulsification capacity of English sole *Parophrys vetulus*, sand sole *Psettichthys melanostictus*, petrale sole *Eopsetta jordani*, lingcod *Ophiodon elongatus*, and orange rockfish *Sebastes pinniger* showed little variation from four catches spaced over a period of 3 months. Frozen storage (-40 C) caused no apparent decrease in emulsifying capacity after 12 months of storage. Addition of 0.02% free fatty acid to white muscle homogenate of rockfish caused a >20% increase in emulsifying capacity. Exposure to 0.04, 0.08, or 0.20% formaldehyde or 50, 100, or 200 mg/1 $CuCl_2$ produced decreases in emulsifying capacities which did not show dose relationships; but 50, 100, or 200 mg/1 CuCl had no significant effect.

1470. Chipman, W.A. 1958. Accumulation of radioactive materials by fishery organisms. Proc. Gulf Caribb. Fish. Inst. 11:97-110.

Laboratory studies are described on uptake, retention and translocation of isotopes of Sr, Co, Zn, and Cs by various species of marine algae, crustacea, fish and molluscs.

1471. Chipman, W.A., T.R. Rice and T.J. Price. 1958. Uptake and accumulation of radioactive zinc by marine plankton, fish, and shellfish. U.S. Fish. Wild. Serv. Fish. Bull. 135, Vol. 58: 279-292.

Zinc concentrations in sea water collected from inshore waters along the Atlantic and Gulf of Mexico coasts averaged 10.6 ug/l (range: trace to 24.56 ug/l). Oysters, clams, and scallops concentrate large amounts of Zn, with oysters containing the greatest amounts by several orders of magnitude. Radioactive zinc added to water was quickly taken up in great amounts by shellfish. Considerable accumulation of the nuclide occurred in gills of these mollusks, with high concentrations in kidneys of scallops, and considerable amounts in hepatopancreas. *Nitzschia closterium*, a marine phytoplankter, took up large amounts of zinc-65 and apparently concentrates zinc, thus allowing its transfer to marine animals. Marine fish rapidly take Zn into the body from the digestive tract, with most being quickly excreted. A rapid uptake of radioactive zinc from an oral dose took place in the kidney, liver, and other internal organs, but loss of the nuclide was also rapid. A slow and long-continued accumulation was observed in bone, integument, and muscle tissues. Although there was immediate loss of contained radioactive zinc when marine fish were returned to flowing seawater, a small percentage remained with only very slight loss over many days.

1472. Chopra, I. 1971. Decreased uptake of cadmium by a resistant strain of *Staphylococcus aureus*. Jour. Gen. Microb. 63:265-267.

Cadmium uptake was estimated by adding Cd-115mCl_2 (final conc.: 10^{-4}M) to exponentially growing cultures of sensitive and resistant strains of *S. aureus*. The nonspecific binding of Cd^{2+} was 170 x 10^{12} ions/ml medium, equivalent to 15% of total Cd^{2+} accumulated by one ml of culture from the sensitive strain. Total uptake of Cd by Cd-sensitive cells was about 15 x that of resistant strains; uptake was about 106 x 10^4 Cd^{2+}/mg dry wt for sensitive organisms. Exchange experiments were performed in which sensitive organisms were labelled for 40 min and then resuspended in non-radioactive medium. About 60% of the Cd-115m was displaced, suggesting that about 40% of the Cd^{2+} taken up by Cd-sensitive staphylococci were bound to some structure within the cell rather than adsorbed adventitiously to the surface.

1473. Chow, T.J., C.C. Patterson and D. Settle. 1974. Occurrence of lead in tuna. Nature 251:159-161.

Lead content of pectoral fin tissue of yellowfin tuna *Neothunnus macropterus* was 5.3 mg/kg wet wt; for skipjack *Katsawanus pelamis* this was 4.1; and for albacore *Thunnus alalunga*, 0.45. Albacore muscle contained 0.0002 to 0.0003 mg/kg wet wt. Tuna epidermis concentrated lead at comparatively high levels: 1.4 to 1.7 mg/kg wet wt. Tuna scales and dermis contained 0.06 and 0.01 mg Pb/kg wet wt, respectively. Commercial canned tuna had lead concentrations of 0.10 to 0.93 mg/kg wet wt, suggesting that industrial lead contamination was 1,000x greater than biological uptake.

1474. Chow, T.J., H.G. Snyder and C.B. Snyder. 1976. Mussels (*Mytilus* sp.) as an indicator of lead pollution. Science Total Envir. 6:55-63.

Lead in *Mytilus californianus* and *M. edulis*, collected along the Pacific coast from Piedras Blancas, California to Punta Banada, Baja California was determined by isotope dilution method and showed a definite correlation between lead content and man's activity along the coastal zone. For regions in California such as Piedras Blancas, Cayuco and Gaviota, which are sparsely populated, Pb content of soft parts of *M. californianus* was low with means ranging from 0.32 to 0.85 mg/kg wet wt. Highest average for *M. californianus* was found in La Jolla specimens, at 7.96 mg/kg dry wt. *Mytilus edulis* from docks and pilings in marinas and bays contained up to 33 mg/kg dry wt (Anaheim Bay); gills contained highest amounts of Pb, followed by stomach. No difference was observed in average isotope ratios of Pb in both species.

1475. Christiansen, M.E. and J.D. Costlow, Jr. 1975. The effect of salinity and cyclic temperature on larval development of the mud-crab, Rhithropanopeus harrisii (Brachyura: Xanthidae) reared in the laboratory. Marine Biology 32:215-221.

Larvae of R. harrisii were reared to first or second crab stages in 11 combinations of salinities and cyclic temperatures. Larvae survived to megalops and first crab stages in all salinities and cycles of temperature other than 5°/oo S at 30 to 35 C. Best survival to megalops (94%) and first crab (90%) stages occurred in 20°/oo S, 20 to 25 C. Duration of larval stages was affected significantly by temperature; salinity effects were inconsistent. Development to first crab stage was shortest in 20°/oo S, 30 to 35 C (mean 12.3 days), and longest in 5°/oo and 35°/oo S, 20 to 25 C (mean 22.6 days and 21.6 days, respectively). Megalops larvae reared in 35°/oo S at all cycles of temperature, as well as larvae in 20°/oo and 25°/oo S, 30 to 35 C, showed abnormalities, with highest percentage occurring in 35°/oo S, 30 to 35 C. Authors suggest that larval development of R. harrisii is strongly influenced by environmental factors and not solely related to genetic differences.

1476. Ciereszko, L.S., E.M. Ciereszko, E.R. Harris and C.A. Lane. 1963. Vanadium content of some tunicates. Comp. Biochem. Physiol. 8(2):137-140.

In 12 ascidian species of the order Phlebobranchia, V occurred at levels of 206 to 4123 mg/kg organic dry weight. Centrifuged blood cells of Ascidia nigra had 14.6 g V/kg wet wt. Vanadium was not detected in four species of salps: Salpa democratica, S. maxima, S. confederata and Ihlea punctata. V was not detected in ascidians of the families Synoicidae, Polycitoridae and Styelidae. Eggs of Phallusia mamillata had 0.17 g V/kg dry wt.

1477. Cintrón, G., W.S. Maddux and P.R. Burkholder. 1970. Some consequences of brine pollution in the Bahiá Fosforescente, Puerto Rico. Limnology Oceanography 15(2):246-249.

Brine pollution from a sea-salt works occasionally flows into Bahiá Fosforescente causing stagnation, severe anoxia and accumulation of hydrogen sulfide (89 ml/liter) with consequent toxic effects on local flora and fauna including several species of algae and higher plants, lobsters (Panuluris sp.) and fish (Jenkinsia). The bottom brine (salinity 57°/oo) constitutes a lethal trap which accumulates and kills phytoplankton so that the water turns yellow-green and reaches a chlorophyll a (actually pheophytin) content of about 2,000 ug/l as compared with chlorophyll levels of about 4 ug/l in the normal surface water. Colonization of the bay bottom by benthic plants and animals may have been prevented by limited light and intermittent brine pollution since the adjacent salt works was established in 1937.

1478. Clausen, C.D. and A.A. Roth. 1975. Estimation of coral growth rates from laboratory ^{45}Ca-incorporation rates. Marine Biology 33:85-91.

Calcification ratios were obtained for 2 species of hermatypic corals by incubating apical (fast growing) portions of freshly collected coral branches in Ca-45. Results, in ng/mm^2/h were 483 and 2304 for side and end cores, respectively, for Porites compressa and 73 and 415 for lateral and terminal regions of Pocillopora damicornis. Ca-45 exchange across the coenosarc was insignificant. P. damicornis demonstrated diurnal fluctuations with the calcification rate at noon being twice as rapid as at midnight. Growth rates, calculated from Ca-45 incorporation data, were 20 and 6 mm/yr for P. compressa and P. damicornis, respectively, and compare favorably with field growth rates of 24 and 14 mm/yr.

1479. Cleland, K.W. 1953. Heavy metals, fertilization and cleavage in the eggs of Psammechinus miliaris. Exp. Cell Res. 4:246-248.

Copper sulphate additions, in mg/l, had the following effects on sea urchin embryogenesis: 1.6—no sperm penetration; 0.8—no membrane elevation but mostly normal and polyspermic cleavage; 0.4—excentric membrane elevation; 0.16—no effect. Membrane elevation was suppressed by 124 mg Pb/l. Zn additions, in mg/l, caused following effects: 6.5—no sperm penetration; 0.65—no elevation of fertilization membrane, abnormal cleavage; 0.065—separation of fertilization membrane, cleavage abnormalities and polyspermic cleavage.

1480. Clemens, H.P. and K.E. Sneed. 1958. The chemical control of some diseases and parasites of channel catfish. Prog. Fish-Cult. 20(1):8-15.

LC-50 (72 hr) values of two prophylactic compounds, pyridylmercuric acetate (80% active) and phenylmercuric acetate (10% solution), to catfish Ictalurus punctatus, were 0.49 and 0.60 mg/l, respectively. Pharmaceutical worth of these compounds to fish is discussed.

1481. Clendenning, K.A. and W.J. North. 1959. Effects of wastes on the giant kelp, Macrocystis pyrifera. In: Pearson, E.A. (ed.). Proc. 1st Conf. Waste Disposal Marine Environ., Berkeley, Calif.: 82-91.

Effects of sewage effluent, organic and inorganic pollutants on *M. pyrifera* in the field and laboratory were studied. The following concentrations in mg/l of inorganic ions caused 50% inactivation of photosynthesis in bottom kelp fronds during 4 day exposure: 0.05 for Hg, 0.1 for Cu, 2.0 for Ni, 5.0 for Cr^{+6}, 10.0 for Zn, and >10.0 for Pb.

1482. Cocoros, G., P.H. Cahn and W. Siler. 1973. Mercury concentrations in fish, plankton and water from three western Atlantic estuaries. Jour. Fish Biol. 5:641-647.

For Core Sound, Chesapeake Bay and Oyster Bay, mercury levels, in mg/kg dry wt, were 0.11 to 0.13 for plankton (primarily phytoplankton), 0.19 for plankton (primarily zooplankton) and 0.27 to 0.50 for menhaden *Brevoortia tyrannus*. High visceral Hg contents in fish suggested food chain uptake. Authors concluded, however, that no evidence of strong food chain intensification exists.

1483. Coleman, R.D., R.L. Coleman and E.L. Rice. 1971. Zinc and cobalt bioconcentration and toxicity in selected algal species. Botanical Gazette 132:102-109.

Growth inhibition and bioaccumulation of Zn and Co in 3 species of freshwater algae was investigated. Zinc adversely affected growth of *Pediastrun tetras* and *Euglena vividis* at 18.0 mg/l in 3 weeks, but *Chlorella vulgaris* was not affected at 35.5 mg/l in a similar period. Concentrations of 4.2 mg/l Zn promoted growth of all species. Concentrations of cobalt above 0.04 mg/l, *i.e.* 0.55 mg/l and higher, retarded growth of all species. The 3 species accumulated Zn and Co on exposure to high environmental levels. For zinc, concentration ranged from 0.1 mg/kg dry wt at 1.88 mg/l environmental Zn^{2+} to 80 mg/kg dry wt at 35.5 mg/l Zn^{2+}. Similar trends were exhibited for cobalt, with final concentration factors for both Zn and Co ranging between 1400 and 2446 for all species and concentrations tested. It was concluded that algae might accumulate Zn and Co to the point where they were toxic in the food web. On the other hand these species might be effective as biological filters for waters polluted by Zn and Co.

1484. Collier, A. 1953. Titanium and zirconium in bloom of *Gymnodinium brevis* Davis. Science 118:328.

Total solids (33.7 g/l) of a red-tide dinoflagellate bloom in the Gulf of Mexico contained 0.01 to 0.1% of titanium and 0.001 to 0.01% zirconium.

1485. Colwell, R.R. and J.D. Nelson, Jr. 1974. Bacterial mobilization of mercury in Chesapeake Bay. Proc. Inter. Conf. Transport Persistent Chem. in Aquatic Ecosys., Ottawa, Canada: III:1-10.

The total number of mercury-resistant bacteria is an index of microbiological Hg transformation. There was a greater number of resistant populations associated with plankton than with water or sediments. Resistance and metabolism of Hg^{2+} and PMA (phenylmercuric acetate) are related and inducible in *Pseudomonas*. PMA metabolism ceased at <8.2% seawater. Percentage of Hg resistant bacteria in bay sediments peaks sharply at 30% in the spring.

1486. Colwell, R.R. and J.D. Nelson, Jr. 1975. Metabolism of mercury compounds in microorganisms. U.S. EPA Rept. 600/3-75-007. U.S.EPA, Office Res. Dev., Envir. Res. Lab., Narragansett, R.I.: 84 pp.

Aerobic heterotrophic bacteria, resistant in varying degrees to mercuric ion, organomercurials, PMA (phenylmercuric acetate) and Me HgCl (methylmercuric chloride), were isolated from water, sediment, and plankton of Chesapeake Bay. Resistance is derived from ability to degrade Hg compounds with formation of Hg^0, this capability being correlated with ability to grow in presence of these compounds. Hg resistance is also related to conditions of incubation, being lower under anaerobic conditions, and increasing with temperature and extreme salinity conditions (26.5^{o}/oo and 2.6^{o}/oo) while decreasing at intermediate salinities (11.38^{o}/oo). The ionic requirement for activity is met by Mg^{2+} ions alone, with a concentration of 5-10 mM optimum for PMA degradation, and 1.2 to 5.6 mM optimum for resistance, the latter being the approximate average *in situ* concentration of Mg. When resistance to other heavy metal ions was tested, variable results were obtained indicating that resistance is not generalized. Metals tested and range of maximum concentrations survived (in mg/l) were: Al^{3+} 16-167; Pb^{2+} 167; Ag^{+} 1.7-16.7; As^{5+} 501; Co^{2+} 18-334; Cu^{2+} 334; Zn^{2+} 18-167; Cd^{2+} 16-167; Cr^{6+} 1.7-668; and Hg^{2+} 4-50.

Numbers of Hg-resistant, aerobic, heterotrophic bacteria at 6 locations in Chesapeake Bay were monitored over a 17 mo. period, as well as total ambient Hg concentrations in water (0.080 to 0.490 ug/l) and sediment (0.007 to 0.860 mg/kg). Hg resistance reached a reproducible maximum in spring and was positively correlated with dissolved oxygen and sediment Hg concentration and negatively correlated with water turbidity. A relation between mercury resistance and metabolic capability for reduction of mercuric ion to the metallic state was established by surveying a number of $HgCl_2$-resistant cultures. The reaction was also observed in microorganisms isolated by differential centrifugation of water and sediment samples. Hg^{2+} exhibited an average half life of 12.5 d in the presence of $\sim 10^5$ organisms/ml.

Cultures resistant to 6 mg/1 of $HgCl_2$ (4.43 mg/1 Hg) and 3 mg/1 of PMA (1.79 mg/1 Hg) were classified into 8 generic categories. *Pseudomonas* spp. were the most numerous of those bacteria capable of metabolizing both compounds; however, PMA was more toxic and was more selective for *Pseudomonas*. Hg resistant generic distribution was distinct from that of total bacterial generic distribution and differed significantly between water and sediment, positionally, and seasonally. The proportion of non-glucose-utilizing Hg resistant *Pseudomonas* spp. was positively correlated with total bacterial Hg resistance. Concentrations as low as 1.2 ug/1 $HgCl_2$ or PMA inhibited a measurable portion of total population. It is concluded from this study that numbers of Hg-resistant bacteria as established by plate count can serve as a valid index of *in situ* Hg^{2+} metabolism.

The majority of PMA bound to components of the cell envelope; with Hg, in general, impairing normal cell wall and membrane synthesis and function. Concentrations of >1 mg/1 produced a lag phase in the growth pattern, at which time Hg-resistant mutants were selected which were capable of releasing Hg^0 from the growth medium. To determine the role of bacteria in moving Hg through the food chain, short-term experiments with oysters were set up with controls, addition of Hg-resistant bacteria, and addition of Hg-accumulating bacteria. Uptake by oysters was 22%, 39.3%, and 36.9% of initial Hg (10.2 ug/1), respectively. Gills accumulated Hg most rapidly, with average concentration factors of 620, 2974, and 2779, respectively; while average whole body concentration factors were 173, 425, and 390, respectively. It is concluded that bacteria may have a demonstrable effect on Hg accumulation in those food chains which include filter feeding components.

1487. Colwell, R.R., G.S. Sayler, J.D. Nelson, Jr., and A. Justice. 1976. Microbial mobilization of mercury in the aquatic environment. *In*: Nriagu, J.D. (ed.). Environmental Biogeochemistry, *Vol.* 2. Metals Transfer and Ecological Mass Balances. Ann Arbor Sci. Publ., Ann Arbor, Mich.: 437-487.

A total of 364 bacterial isolates resistant to $HgCl_2$ were cultured from Chesapeake Bay; 97.5% of these comprised 7 genera and more than 60% were pseudomonads. Approximately 90% of the 70 strains of phenylmercuric chloride-resistant bacteria were identified. Mercury-resistant bacteria in this study were resistant to $HgCl_2$ at concentrations up to 50 mg/1 after adaptation in $HgCl_2$ or PMA (phenylmercuric acetate) media. There were no significant differences between water and sediment in proportions of Hg-resistant bacteria isolated from 3 sites. Some morphological distortions seen in *Enterobacter* strains grown in media containing 2 μg $HgCl_2$/ml for 24 hrs included lysed cells and cells with abnormal cross wall formation. Oysters *Crassostrea virginica* collected from Tolley Bar region of Chesapeake Bay were dosed with bacteria capable of accumulating mercury on, or in the cell or of reducing and volatizing both organic and inorganic mercury. All three tests were run in a 10 g/l Hg-203 labeled $HgCl_2$ solution. The mercury reducing Pseudomonas strain reduced 25.4 µg $HgCl_2$ to elemental mercury from a solution containing 6 mg $HgCl_2$/l; the mercury-accumulating Pseudomonas strain accumulated 12 µg $HgCl_2$/mg cells/15 min from a solution containing 6 mg $HgCl_2$. After 96 hr, accumulations in whole oysters, in µg Hg/kg wet wt, were 201 for controls, 312 for those with Hg-reducing bacteria and 463 for those with Hg accumulating bacteria. Highest and most rapid accumulations were found in oyster gill tissue with accumulations in µg Hg/kg wet wt, of 647 in controls, 1747 in oysters with mercury-reducing bacteria and 2850 in oysters with mercury-accumulating bacteria.

1488. Conte, F.P. and H.H. Wagner. 1965. Development of osmotic and ionic regulation in juvenile steelhead trout Salmo gairdneri. Comp. Biochem. Physiol. 14:603-620.

Development of seawater adaption preceded seaward migration and smolt transformation by several weeks. Regression of adaptation occurred during terminal stages of migration period. Chronological time is only important in that it determines how long it takes fish to reach a critical size; in steelheads it is 14-15 cm. In non-adapting individuals, Na and Cl do not represent the 85-90% total osmotic concentration found for freshwater fish. This suggests that other types of solutes constitute a vital role in seawater homeostasis and pathogenesis of seawater death. Increased thyroid activity was found during the period of migration but this did not appear to be causally related to seawater adaption.

1489. Conte, F.P., H.H. Wagner, J. Fessler, and C. Gnose. 1966. Development of osmotic and ionic regulation in juvenile coho salmon Oncorhynchus kisutch. Comp. Biochem. Physiol. 18:1-15.

Development of seawater adaptation preceded seaward migration and parr-smolt transformation by 6-7 months with no regression observed following terminal stages of migration period. Seawater survival for various salinities (20-30°/oo) was a function of size and not chronological age. Relative survival times were O. kisutch > Salmo gairdneri > S. salar > S. clarki > S. trutta. Variability of osmotic and ionic regulatory system was indicated by deviation between blood concentrations of freshwater fish (control) and fish exposed to seawater during the premigratory, migratory, and post-migratory periods.

1490. Cook, A.M. and K.J. Steel. 1959. The antagonism of the antibacterial action of mercury compounds. Part IV. Qualitative aspects of the antagonism of the antibacterial action of mercuric chloride. Jour. Pharm. Pharmacol. 11:162-168.

Molar amounts which bracket the no-effect, frank effect responses for antagonism of one mole of mercuric chloride inhibition of E. coli are listed. These values were 1.7 and 2.1 for cysteine, 0.7 and 1.1 for dimercaprol, 1.9 and 2.1 for glutathione, and 1.9 and 2.2 for thioglycollic acid. When used to revive $HgCl_2$-treated cells, larger amounts were needed; horse serum was ineffective. Cells treated with $HgCl_2$ in presence of a nutrient medium derived some protection from media constituents.

1491. Cornell, J.C. 1974. A reduction in water exchange rates in an osmoconforming crab. Amer. Zool. 14:1259.

Data from Libinia emarginate, an osmoconformer, on weight gain, urine production and osmotic concentration suggested that there was a reduction in water exchange when animals were transferred to a dilute medium. This hypothesis was tested by measuring water exchange rate with D_2O. The rate constant in 100% SW was 8.49. After exposure for one hour to 80% SW the value dropped to 5.96, indicating a 30% reduction in water exchange. A possible mechanism for reduction in water exchange was proposed when it was found that transferring animals to a dilute medium caused a reduced heart rate. If reduced heart rate causes reduced flow of blood in gills, this might account for reduced water exchange. Flow rate in gills was not measured. However, when isolated gills were perfused with a peristaltic pump, water exchange was proportional to rate of perfusion. This suggests that changes in circulation may be responsible for changes in water exchange rates.

1492. Cossa, D. 1976. Sorption du cadmium par une population de la diatomée Phaeodactylum tricornutum en culture. Marine Biology 34:163-167. (English summary.)

Uptake of cadmium by the marine diatom P. tricornutum in batch culture as a function of successive growth stages, and of chemical form of cadmium in culture medium, was determined over a 12 day period. Ionic and complexed Cd at 10 ug/l produced up to 16% growth inhibition by the 12th day; chelated Cd had little effect on growth during this period. Concentration of ionic Cd in medium influenced uptake by diatoms: 8300 mg Cd/kg wet wt algae was observed at 1 mg Cd/l; however, when cadmium was chelated by ethylenediaminetetraacetate, uptake was negligible. In absence of chelating agents, uptake varied with growth phase of the culture, with major part of uptake by adsorption.

Two opposite phenomena seem to be responsible for the processes observed: adsorption of cadmium on the cell walls followed by a gradual elution (desorption) by external metabolites. Author suggests that Zn (from culture media) and Cd compete for adsorption sites.

1493. Costa, M.R.M. and M.I.C. da-Fonseca. 1967. Teor do arsenico em mariscos. Revista Portuguesa de Farmacia 17(1):1-19. (In Portuguese, English summary.)

Arsenic levels in mg/kg dry wt from edible parts of 21 species of molluscs ranged from 1.3 to 129.6, with a range of means from 7.1 to 83.8. Edible parts of 9 species of crustacea contained 5.6 to 220.2 mg As/kg dry wt with a range of means of 8.6 to 96.2.

1494. Coulson, E.J., R.E. Remington and K.M. Lynch. 1935. Metabolism in the rat of the naturally occurring arsenic of shrimp as compared with arsenic trioxide. Jour. Nutrition 10(3):255-270.

In an analysis of seafood, shrimp contained the highest concentrations of As: 1.2 to 41.6 mg/kg wet, or 4.9 to 171.0 mg/kg dry. A seasonal effect on As levels was seen in shrimp from one area, with highest levels in Oct. and lowest levels in May and June. Using shrimp as an organic As source, rats were fed a stock diet (0.2 mg As/kg), a low As shrimp diet (1.2 mg As/kg), a high As shrimp diet (17.7 mg As/kg), a stock diet with inorganic As_2O_3 (17.9 mg As/kg) and a low As shrimp plus As_2O_3 diet (17.9 mg As/kg), for one year. During the first 3 months an equilibrium level of As was reached and maintained in rat bodies, being 18% of ingested As_2O_3, compared with 0.7% if "shrimp As" was ingested. Livers of rats contained ∿3 mg As/kg wet when fed high As shrimp, while rats fed inorganic As contained ∿55 mg As/kg wet. No rats showed evidence of toxicity in growth, physical appearance, activity, or in histological examination of liver, spleen and kidney. Rats excreted nearly 100% of "shrimp As," but only 20% of inorganic As; whereas humans excreted 114% of "shrimp As" and from 74 to 103% of inorganic As. Results indicated that As held in a complex combination in shrimp upon digestion in an animal organism, will not release As but rather a soluble and readily diffusible product rapidly eliminated by kidneys.

1495. Courtois, L.A. and R.D. Meyerhoff. 1975. Effects of copper exposure on water balance. Bull. Environ. Contamin. Toxicol. 14(2):221-224.

Plasma volume of the freshwater striped bass *Roccus saxatilis* was 2.50-2.86% of total body weight. After exposure to 1 mg/l Cu (as $CuSO_4$) for 6 to 15 minutes, an expansion of 0.95-0.97% was found and suggests that copper affects the exterior border of gill membrane to produce passive osmotic diffusion.

1496. Cowen, J.P., V.F. Hodge and T.R. Folsom. 1976. *In vivo* accumulation of radioactive polonium by the giant kelp, *Macrocystis pyrifera*. Marine Biology 37:239-248.

Rates of accumulation of Po-210 by young, growing lamina of kelp from La Jolla beds were 0.78 x 10^{-9} pCi/cm^2 sec (1.73 x 10^{-9} dpm/cm^2 sec) and 1.17 x 10^{-9} pCi/cm^2 sec (2.60 x 10^{-9}dpm/cm^2 sec) for observed and growth-corrected data, respectively. Inert, foulable surfaces exposed to kelp bed environment had Po-210 accumulation rates of 0.64 x 10^{-9} pCi/cm^2 sec (1.42 x 10^{-9} dpm/cm^2 sec).

1497. Cowey, C.B., T.L. Coombs and J.W. Adron. 1976. The renal and serum concentrations of calcium, magnesium and phosphorous in captive and wild turbot (*Scopthalmus maximus*). Marine Biology 38:111-115.

Concentrations of Ca, Mg and P in kidney, serum, and ultrafiltrates of serum in wild flatfish were compared to those reared in captivity and which exhibited a hepato-renal syndrome of renal tubule calcification. No differences in renal Ca or Mg were found. Serum from wild turbot contained significantly higher total and ultrafilterable Mg than serum from turbot reared in captivity. No relationship, causal or indirect, was suggested between hepato-renal syndrome and disturbance of Ca/Mg metabolism.

1498. Cowgill, U.M. 1976. The chemical composition of two species of *Daphnia*, their algal food and their environment. Science Total Environ. 6:79-102.

D. magna and *D. pulex* cultured in spring water and fed *Euglena gracilis* supplemented occasionally with a mixed algal culture contained 54 detectable elements, while the water had 53. Major differences were noted between the two species of *Daphnia*, with *D. magna* exhibiting greater accumulation in mg/kg dry wt of K (13,839), Na (1,180), Ca (76,643), Sr (81.9), and *D. pulex* having a greater Co content (3.3). *Daphnia* and algae contained different amounts of Na, K, Mg, Cu, Zn, Al, Sc, La, Nd, Sn, Ti, Fe, Mn, Ni, Zr, Cu, Ag, Be, Si, Pb, and Hg. Other elements determined were Rb, Cs, Li, Cd, Ba, Ce, Pr, Sm, Eu, Gd, Dy, Er, Yb, Ga, B, Hf, As, Bi, V, Nb, Se, Cr, Mo, and Co.

Chemical composition of Daphnia is governed by mixed algal culture and the spring water. Daphnia rejected E. gracilis which did not contribute to their chemical composition. Composition of algal cultures is apparently governed by that of the spring water.

1499. Cowgill, U.M. and C.W. Burns. 1975. Differences in chemical composition between two species of Daphnia and some fresh-water algae cultured in the laboratory. Limnol. Oceanog. 20:1005-1011.

Daphnia pulex and D. magna were cultured in spring water and fed with a monoculture of Euglena gracilis and occasionally with a mixed algae culture containing mainly Chlorophyceae. Fifty-three elements were detected in the spring water and fifty-four in plankton. By comparing the mean concentration (dry wt. basis) of the 2 species of Daphnia and the 2 algae cultures, the following concentration factors of Daphnia over algae were found: Ca (6.9), Na (4.5), Sc (2), Nd (2), La (2), Zr (2), and Ni (2). Algae, on the other hand, accumulated greater concentrations of Mo (13.4), Fe (12.2), Mg (10.6), Sn (8.1), Ag (7.5), Ti (6.1), Be (3.7), Cu (3.0), Zn (2.7), Mn (2.3), Al (1.7), As (1.6), Co (1.7), K (1.5), Pb (1.3), Hg (1.4), Si (1.1), and contain about the same concentration of Cd as Daphnia. Concentration of Ca was 2.1 times higher in D. magna than in D. pulex.

1500. Cox, H.E. 1925. On certain new methods for the determination of small quantities of arsenic, and its occurrence in urine and in fish. Analyst 50:3-11.

Ranges in concentrations (mg/kg) of arsenic as As_4O_6 in edible fish muscle were: whiting 0.1-0.4, hake 0.2-0.3, john dory 0.1, brill 0.1-0.3, halibut 0-0.3, turbot 0.2-1.8, perch 0.8, plaice 0.3-3.0, sole 0.1-0.3, herring 0.1-0.8, cod 0.1-2.0, haddock 0.1-0.6, and mackerel 0.1-0.5. It was noted that certain Whitstable oysters contained up to 3.7 mg/kg As, and algae up to 0.7 mg/kg As. Fish, particularly plaice, are believed to accumulate As from bivalves, algae, and other food organisms. Arsenic is subsequently transferred to humans consuming fish, with quantities of As excreted in urine within 24 hours.

1501. Craig, S. 1967. Toxic ions in bivalves. Jour. Amer. Osteop. Assn. 66:1000-1002.

Two species of edible molluscs Venus mercenaria and Spisula sp. were analyzed for Pb, Cu, and Hg. Venus from Cape Henlopen on the Delaware Bay contained concentrations (in mg/kg wet wt) of 1.0 Pb, 0.9 Cu, and 1.1 Hg, while Spisula had 7.3 Pb, 1.1 Cu, and 0.8 Hg. Specimens from Woods Hole of *Venus* contained 2.5 mg/kg Pb, 19.2 Cu, and 2.3 Hg, while *Spisula* contained 1.1 Pb, 0.7 Cu, and 0.8 Hg.

1502. Cugurra, F. and G. Maura. 1976. Mercury content in several species of marine fish. Bull. Environ. Contamin. Toxicol. 15:568-573.

Mercury in canned tuna, anchovies, sardine and mackerel, frozen umbina, dried and fresh cod fish and sardines and oculata from Genoa, Italy was determined. Total mercury in mg/kg wet wt of canned tuna was 0.64 for *Parathunnus obesus*, 0.27 for *Neothunnus macropterus*, 0.27 for *Katsuwonas pelamis* and 1.32 for *Tunnus thynnus*. Total mercury in other species of fish were 0.41 for anchovy *Engraulis encrasicholus*, 0.21 for sardines *Clupea sardina* bought in Genoa, 0.16 for *C. sardina* fished and packed in Spain, and 0.25 for mackerel *Scomber scomber*. Total Hg for non-canned fish, was 0.48 for *Clupea sardina*, caught near Genoa, Italy, 2.59 for *Oblata melamura*, caught near Genoa, 0.70 for *Umbrina cirrhosa* and 0.326 for *Gadus morrhua*.

1503. Culkin, F. and J.P. Riley. 1958. The occurrence of gallium in marine organisms. Jour. Mar. Biol. Assn. U.K. 37:607-615.

Gallium, copper, aluminum and iron levels, in mg/kg dry wt, were: 0.01 to 0.56 Ga, 5.6 to 86 Cu, 34 to 4420 Al, and 34 to 4680 Fe for algae; 0.18 Ga, 111 Cu, 973 Al and 1148 Fe for *Ramulina*, a foraminiferan; 0.93 Ga, 59.5 Cu, 3700 Al and 4040 Fe for *Halichondria panicea*, a sponge; 0.05 Ga, 62 Cu, 435 Al and 438 Fe for *Alcyonium digitatum*, a coelenterate; 0.03 to 0.36 Ga, 35 to 29 Cu, 166 to 1041 Al and 146 to 1045 Fe for crustacea; 0.008 to 0.036 Ga, 1.6 to 7.9 Cu, 32 to 174 Al and 41 to 239 Fe for shells and 0.007 to 0.16 Ga, 37 to 102 Cu, 186 to 346 Al, and 86 to 1415 Fe for soft parts of molluscs; 0.02 to 0.35 Ga, 20 to 90 Cu, 159 to 1830 Al and 149 to 1700 Fe for echinoderms. Viscera and digestive organs of molluscs, *Pecten maximus*, *Buccinum undatum*, *Chlamys opercularis* and *Porania pulvillus* contained elevated Ga levels, presumably from ingested inorganic material. Ga:Al ratio varied from 1 to 7 x 10^{-4} (average 2 to 3 x 10^{-4}), which compares well with average Ga:Al ratio of lithosphere, and contrasts with ratio of 25 x 10^{-4} for seawater. Authors concluded that organisms examined derived their Ga, Al and Fe from bottom muds rather than from seawater.

1504. Cumbie, P.M. 1975. Mercury levels in Georgia otter, mink, and freshwater fish. Bull. Environ. Contamin. Toxicol. 14(2):193-196.

Mercury levels are reported in aquatic mammals and fish from a region of the Georgia Lower Coastal Plain; this area is not associated with recognized point sources of mercury contamination. Mercury concentrations detected in hair of otter Lutra canadensis ranged from 9.3 mg/kg to 67.9 mg/kg. An adult male otter with 35.3 mg/kg Hg in hair had 1.97 mg/kg Hg in skeletal muscle. Mink Mustela vison hair mercury levels ranged from 2.3 mg/kg to 17.3 mg/kg. Mean mercury levels in mg/kg wet wt from axial muscle of various species of fish were: largemouth bass Micropterus salmoides 0.44, chain pickerel Esox niger 0.81, bowfin Amia calva 0.45, gar Lepisosteus sp. 0.42, chubsucker Erimyzon oblongus 0.14, and redfin pickerel Esox americanus 0.39.

1505. Cunningham, P.A. and M.R. Tripp. 1975. Factors affecting the accumulation and removal of mercury from tissues of the American oyster Crassostrea virginica. Marine Biology 31: 311-319.

Adult oysters were held in seawater containing 10 or 100 ug/l of mercury as mercuric acetate for 45 days. After 45 days, average mercury tissue concentration was 91,600 and 12,100 ug/kg wet wt in the 100 and 10 ug/l groups, respectively. A slight decline in mercury residues in the 100 ug/l group during the accumulation period was attributed to spawning. Clearance of mercury from tissues was studied in a constant temperature regime (25 ± 2 C) for 25 days and in a declining temperature regime (25 to 5 C) for 80 days by exposing treated adults to estuarine water with no mercury added. The biological half-life of mercuric acetate was 16.8 and 9.3 days in the 25 C temperature regime, and 35.4 and 19.9 days in the declining temperature regime, for the 10 and 100 ug/l groups, respectively. Smaller oysters (up to 7 g) consistently accumulated more mercury per gram wet wt than larger oysters (7 to 20 g) in populations exposed to 10 and 100 ug/l mercury.

1506. Cunningham, P.A. and M.R. Tripp. 1975. Accumulation, tissue distribution and elimination of $^{203}HgCl_2$ and $CH_3{}^{203}HgCl$ in the tissues of the American oyster Crassostrea virginica. Marine Biology 31:321-334.

Oysters were exposed for 3 days to mercury-203 labeled $HgCl_2$ or CH_3HgCl added directly to artificial seawater or added preconcentrated on marine diatoms Phaeodactylum tricornutum. The concentration of mercury in 5 tissues was measured for 45 days after mercury was removed from the ambient water. At the beginning of depuration, highest concentrations of mercury in tissues were attained in: gill > digestive system > mantle > gonad > muscle in oysters exposed to water containing mercury; and in digestive system > gill > mantle > gonad > muscle in oysters fed labeled algae. This same distribution pattern is seen for both chemical forms of mercury. Although initial pattern of accumulation was identical for both mercury compounds within each exposure group, the fate of accumulated mercury was different after 45-days depuration. In oysters accumulating mercury directly from seawater, inorganic mercury residues rapidly declined in gill and digestive tissue, but were slowly reduced in mantle, gonadal, and muscle tissue. This pattern was duplicated by oysters exposed to methyl mercuric chloride in seawater except that gonadal and muscle residues greatly increased during depuration. In oysters ingesting labeled P. tricornutum cells, mercuric chloride and methyl mercuric chloride residues rapidly declined in gill and digestive tissue, remained constant in the mantle, but sharply increased in gonadal and muscle tissue during depuration.

1507. Cutshall, N. 1974. Turnover of zinc-65 in oysters. Health Physics 26:327-331.

Uptake and loss of Zn-65 by Pacific oysters Crassostrea gigas are fitted by solutions to a first-order, linear differential equation that describes "single-compartment" isotope substitution kinetics. Rate constants for loss are related to rate constants for uptake and to steady-state concentration factors for stable Zn and Zn-65. Single-compartment solutions adequately fit uptake and loss data from field experiments extended as long as several hundred days; therefore, author concludes that either individual organs of oysters have closely similar turnover-rate constants for Zn, or at least that dominant organs in whole-body Zn content turnover at similar rates. Rate constant estimated from loss data is 5490 days and that from uptake data is 4930 days. Apparent importance of multiple compartments can be affected in experiments where uptake times are short.

1508. Dabrowski, K.R. 1976. The effect of arsenic on embrional development of rainbow trout (Salmo gairdneri, Rich.). Water Research 10:793-796.

Survival of trout eggs increased as As^{+5} concentration of medium increased from 0.05 to 50.0 mg/l, but survival was not related to As^{+3} level over this concentration range. Accumulation rates of As^{+3} and As^{+5} were related to ambient concentrations.

1509. D'Agostino, A. and C. Finney. 1974. The effect of copper and cadmium on the development of Tigriopus japonicus. In: Vernberg, F.J. and W.B. Vernberg (eds.). Pollution and Physiology of Marine Organisms. Academic Press, New York: 445-463.

Egg development in T. japonicus, an estuarine copepod, was inhibited by exposure to 0.04 mg Cd^{2+}/l or 0.064 mg Cu^{2+}/l. Cadmium was acutely toxic to ovigerous females and nauplii at 4.4 mg/l in 72 hrs; Cu at 6.4 mg/l in 48 hrs. Females did not become ovigerous when exposed to 4.4 ug Cd^{2+}/l and 4.6 ug Cu^{2+}/l simultaneously. Phenylmercuric acetate, in concentrations of 5.96 to 0.00596 mg Hg^{2+}/l killed ovigerous females in 4 to 72 hrs. Acute toxicity tests were conducted with residues from industrial mycelial fermentation operations. These contained in mg/kg wet wt: Cd, 0.03; Cr, 2.6; Cu, 2.8; Mn, 9.7; Mg, 0.02; Ni, <0.06; Fe, 160; and Zn, 360. At 100 mg residue/l females did not produce eggs; at 1000 mg/l death occurred within 6 days.

1510. Dalton, J.C. 1958. Effects of external ions on membrane potentials of a lobster giant axon. Jour. Gen. Physiol. 41(3): 529-542.

Decrease in external concentration of sodium caused a reversible reduction in amplitude of action potential of the lobster giant axon and its rate of rise, but resting potential was not affected. Changes were of same order of magnitude, but greater than would be predicted for an ideal Na electrode. Resting potential was inversely related to external K concentration. Lowering external Ca below 1 g/l caused a reduction in resting and action potentials, and occasional occurrence of repetitive activity. Decrease in action potential was not solely attributable to a decrease in resting potential. Increase of external Ca from 1 to 2 g/l caused no change in transmembrane potentials. Variations of external Mg concentration between 0 and 1.2 g/l had no measurable effect on membrane potentials. Studies did not indicate a clear choice between use of seawater and perfusion solution as better external medium for studies on lobster nerve.

1511. Dalton, J.C. 1959. Effects of external ions on membrane potentials of a crayfish giant axon. Jour. Gen. Physiol. 42(5): 971-982.

Magnitude of action potential in crayfish giant axon was a linear function of the log of external sodium concentration, as predicted for an ideal Na electrode. Resting potential was an inverse function of external K concentration, but behaved as an ideal electrode only at the higher external K concentrations. Decrease in external Ca resulted in a decrease in both resting potential and action potential; an increase in external Ca above normal had no effect on magnitude of transmembrane potentials. Magnesium could partially substitute for Ca in maintenance of normal action potential magnitude, but appeared to have very little effect on resting potential. All ionic effects were completely reversible.

1512. Danil'chenko, O.P. and N.S. Stroganov. 1975. Evaluation of toxicity to the early ontogency of fishes of substances discharged into a body of water. Jour. Ichthyology 15(2): 311-319.

Highest concentration tested of triethyl lead chloride (TELC) not affecting development of various species of freshwater fish prolarvae was 0.1 mg/l. However, larval symptoms such as elongation of heart chambers, pericardium dropsy, and absence or retardation of inflation of swim bladder, occurred at exposures above 0.01 mg TELC/l.

1513. Davidson, D.E. 1974. The effect of salinity on a marine and a freshwater ascomycete. Canad. Jour. Botany 52:553-563

An isolate of *Lulworthia medusa*, a marine fungi, grew significantly better in seawater than freshwater. Growth of *Ophiobolus graminis*, a freshwater isolate, was reduced by 50% in seawater; growth of both species was similar in natural and artificial seawater. Neither species grew under anaerobic conditions. Respiration of the freshwater species is reduced in seawater; percent reduction was about equal to reduced growth in seawater, as compared to freshwater. Respirational rates of *L. medusa* in sea and freshwater were similar. Yet growth in seawater was much greater than in freshwater. Consequently, it was proposed that respiratory energy produced in a freshwater environment was used for cellular functions other than biomass increase. In contrast to the marine isolate, metabolic processes of *O. graminis* were severely affected by seawater.

1514. Davidson, D.E. 1974. Wood-inhabiting and marine fungi from a saline lake in Wyoming. Trans. Brit. Mycol. Soc. 63(1):143-149.

Forms known as marine fungi *Monodictys pelagica*, *Nais inornata* are reported from the saline but non-marine environment of a $MgSO_4 \cdot Na_2SO_4$ lake in southeastern Wyoming. Occurrence of marine fungi in saline lakes without a recent outlet to the sea is unusual.

1515. Davies, A.G. 1974. The growth kinetics of *Isochrysis galbana* in cultures containing sublethal concentrations of mercuric chloride. Jour. Mar. Biol. Assn. U.K. 54:157-169.

The marine alga *I. galbana* concentrated intracellular mercury at levels up to 1 g/l after exposure to 10.5 ug Hg/l for 5 days. Specific cellular growth rate was linearly reduced by increasing intracellular levels of Hg, with no growth at 2 g Hg/l. Loss by volatilization of reduced Hg from cultures allowed growth to resume, eventually yielding control population levels. Intracellular Hg increased cell volumes up to 2x at highest sublethal concentrations examined. Author suggests that Hg combines with certain sulphur-containing compounds which are essential for successful cell division.

1516. Davies, A.G. 1976. An assessment of the basis of mercury tolerance in Dunaliella tertiolecta. Jour. Mar. Biol. Assn. U.K. 56:39-57.

Specific growth rate of a green flagellate was unaffected by mercury concentrations up to 2.03 μg at/l. At 10 μg at/l it was reduced by 84% but growth continued, giving a final level of cell material only 13% below that of a mercury-free control. At this concentration, growth was largely uncoupled from division and giant cells were produced. This might be due to effect of mercury upon production of methionine which is implicated in process of cell division. Mercury tolerance was investigated in terms of (1) mercury detoxication in the culture medium by complex or compound formation between metal and metabolites produced by cells (2) concentration of sulphydryl groups both within cells as possible sequestration sites and in cell membrane where any molecular disruption and permeability changes produced by the metal first occur (3) absence of cellular potassium leakage and (4) resistance of cell membrane to uptake of mercury ions. Results indicated that Hg tolerance of D. tertiolecta is partly related to slower rate of Hg accumulation, but is largely due to detoxication of Hg within cell possibly by precipitation of a highly insoluble Hg compound.

1517. Davies, P.H., J.P. Goettl, Jr., J.R. Sinley, and N.F. Smith. 1976. Acute and chronic toxicity of lead to rainbow trout Salmo gairdneri, in hard and soft water. Water Research 10:199-206.

Static bioassays conducted in hard water (353 mg/l as $CaCO_3$) produced LC-50 (96 h) range of 1.32 to 1.47 mg dissolved Pb/l vs total Pb LC-50's (96 h) of 542 to 471 mg/l. In flow-through bioassay in soft water (28 mg/l as $CaCO_3$), LC-50 (96 h) of 1.17 mg/l expressed as either dissolved or total Pb was obtained. Symptoms of chronic low-level exposure included occurrence of black tails, lordoscoliosis, paralysis, muscular atrophy and caudal fin erosion. Maximum acceptable toxicant concentrations (MATC's), as determined by black tail occurrence, the most sensitive criterion used, were between 18.2 and 31.7 micrograms dissolved Pb/l vs 120 to 360 ug total Pb/l in hardwater. In soft water, where exposure to Pb was initiated at eyed egg stage of development, the MATC was between 4.1 and 7.6 ug/l. With exposure to Pb beginning after hatching and swim-up of fry, the MATC was between 7.2 and 14.6 ug/l. Authors conclude that fish were more sensitive to Pb when exposed as eggs.

1518. Davis, J.J,, R.W. Perkins, R.F. Palmer, W.C. Hanson and J.F. Cline. 1958. Radioactive materials in aquatic and terrestrial organisms exposed to reactor effluent water. *In*: Proc. Second U.S. Int. Conf. Peaceful Uses Atomic Energy, Vol. 18 - Waste Treat. Environ. Aspects of Atomic Energy, Geneva: 423-428.

Accumulation of radioisotopes by aquatic organisms downstream from Hanford nuclear reactors on the Columbia River was measured. Green algae, *Stigeoclonium lubricum*, contained higher levels and greater diversity of Sc-46, Cr-51, Mn-54, Mn-56, Fe-59, Co-60, Cu-64, Zn-65, As-76, Zr-95, Nb-95, Ru-103, Cs-137, Ba-140, La-140, Ce-141, Np-239, and Sr-90, than other organisms analyzed: sponge *Spongilla lacustris*; insect larvae *Hydropsyche cockerelli*; gastropod *Stagnicola nuttaliana*; crayfish *Astacus trowbridgii*; minnow *Richardsonius balteatus*; several other species of teleosts including sucker *Catostomus macrocheilus*, sturgeon *Acipenser transmontanus*, squawfish *Ptychocheilus oregonensis* and whitefish *Prosopium williamsoni*; and also Barrow goldeneye duck *Bucephala islandica*.

1519. Davis, K.B. and B.A. Simco. 1976. Salinity effects on plasma electrolytes of channel catfish, *Ictalurus punctatus*. Jour. Fish. Res. Bd. Canada 33:741-746.

Plasma sodium and chloride levels of catfish increased after 5-day exposure to 10 and 12 g/l NaCl. Exposure of fish to 4 and 8 g/l for 5 days resulted in plasma electrolyte levels higher than those of fish kept in aged tap water, but were not different from values usually found in freshwater fish. These observed differences may have been due to handling. Tests were performed during several months and no effect due to season was observed. When fish in July (27 C) were exposed to 10 g/l NaCl, plasma electrolyte concentration increased for 48 hrs and then stabilized. Exposure to the same concentration in March (9 C) produced a slow increase of plasma electrolytes throughout the 13 day study. Injection of 100 μg/kg cortisol had no effect on plasma electrolyte increase during 48 hrs after transfer to 12 g/l NaCl.

1520. DeClerck, R., J. Van de Velde, and W. Vyncke. 1973. On the effects of dumped organic industrial waste deriving from the production of proteolytic enzymes on density, distribution and quality of fish and shrimps. Aquaculture 2:323-335.

A one-year study was conducted in a dump area off the Belgian coast in order to define effects of dumped industrial organic wastes resulting from production of proteolytic enzymes. A total of 36 species were examined, with primary emphasis on plaice *Pleuronectes platessa*, dab *Limanda limanda*, sprat *Sprattus sprattus*, whiting *Gadus merlangus*, sole *Solea solea*, and shrimp *Crangon crangon*. The dumped waste consisted of 61.7% water; dry matter was 38.3% diatomaceous earth and 56% organic matter; ash contained 1-5% Ca, P, Al and S, 0.1-0.3% Fe and Mg, 0.03-0.1% B, and 0.01-0.03% Pb, Cu, Ti and Ga. This waste material sinks rapidly to the bottom with a high rate of dispersion. Some obstacle to fishing occurs during a few days after dumping due to waste lumps present. Dumped material showed no negative effects on fish and shrimp stocks. The behavior of shrimps in an aquarium system indicated no adverse effects. The organic waste did not influence the quality and shelf life of shrimps.

1521. DeClerck, R., R. Vanderstappen and W. Vyncke. 1974. Mercury content of fish and shrimps caught off the Belgian coast. Ocean Manage. 2:117-126.

Total mercury was determined in 800 samples of plaice *Pleuronectes platessa*, whiting *Merlangus merlangus*, cod *Gadus morhua*, sprat *Clupea sprattus* and shrimp *Crangon crangon* caught off the Belgian coast during a one-year period. Most of the values were less than 0.25 mg/kg wet wt with highest frequencies occurring between 0.10 and 0.25 mg/kg. Significant positive regressions between length of fish and mercury content were found for male and female whiting and male cod, but not other species. The Hg concentration in seawater off the Belgian coast averages 0.15 ug/l which seems to be normal for surface waters. Sediments contained about twice as much mercury as in more distant water (0.27 vs 0.15 mg/kg). Therefore it was not unexpected that Hg concentrations in Belgian inshore fish appeared higher than from fish caught in distant waters where reported Hg levels were almost exclusively below 0.10 mg/kg.

All analyses on shrimps were made on whole crustaceans. However, a specific investigation on mercury distribution in body of shrimps showed a distribution of 56% in flesh, 32% in cephalothorax, 12% in shell and 0% in telson. Taking into account an average percentage of 30% shrimp flesh, a mean content of 0.186 mg Hg/kg was present in edible flesh. Neither season nor fishing ground had a significant influence on the mercury content of shrimps.

1522. DeJong, L.E.D.D. 1965. Tolerance of *Chlorella vulgaris* for metallic and non-metallic ions. Anton. v. Leeuwenhock 31:301-313.

Preliminary experiments of 3-4 month duration were conducted with the freshwater alga *C. vulgaris* and analytical reagent grades of various metals salts. Highest concentrations tolerated in g atoms/l, are shown below in tabular form; with minor exceptions the same concentration range also produced growth inhibition.

Highest Concentration Tolerated	Element
0.000001 to 0.00001	Co, Ni
0.00001 to 0.0001	Cu, Cd, Hg, Tl, Sb, As
0.0001 to 0.001	Th, Sn
0.001 to 0.01	Be, Ba, U, Sc, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Ti, Zr, V, Nb, Cr, Mn, Fe, Zn, Al, In, Pb, Bi, Se, Te, B
0.01 to 0.1	Li, Na, Cs, Mo, W
0.1 to 1.0	K, Rb, Mg, Ca, Sr

1523. DeMarte, J.A. and R.T. Hartman. 1974. Studies on absorption of P-32, Fe-59, and Ca-45 by water-milfoil (*Myriophyllum exalbescens* Fernald.). Ecology 55:188-194.

Autoradiographs and radioactivity measurements provided direct evidence that P-32, Fe-59 and Ca-45 were absorbed by roots of *M. exalbescens*, an aquatic vascular plant, and translocated to shoot tissues. Data from experiments designed to compare effects of substrate type (sand or muck) and presence or absence of light showed that Fe-59 was not absorbed and translocated to the shoot when rooted in sand and maintained in light during uptake period. Positive results for Fe-59 uptake were obtained for all other treatments. Upward translocation of Ca-45 occurred only when plants were rooted in sand and maintained in light. Autoradiography showed that Fe-59 and Ca-45 were generally distributed throughout shoot tissues, with a noticeable accumulation of each in stem.

1524. DeSilva, S.S. and P.A.B. Perera. 1976. Studies on the young grey mullet, *Mugil cephalus* 1. - Effects of salinity on food intake, growth and food converstion. Aquaculture 7:327-338.

Effects of different levels of salinity (30, 20, 10, and $<1^{o}$/oo) on growth, food intake and food conversion efficiency of young grey mullet were studied. Daily food intake was variable at all 4 salinities; intake was salinity-dependent when food was presented in excess. There was no appreciable difference in rate of growth when fed 8% of body weight or in excess; maximum growth efficiency occurs at

20^{o}/oo. Percentage conversion efficiency of fish fed on an excess diet at 10^{o}/oo was highest; with a constant ration percent conversion efficiency decreased with increasing salinity.

1525. Dick, J. and L.I. Pugsley. 1950. The arsenic, lead, tin, copper, and iron content of canned clams, oysters, crabs, lobsters, and shrimps. Canad. Jour. Res. F. 28:199-201.

A survey of heavy metal content of canned shellfish and crustaceans sold on the Canadian market has been made. With the exception of one sample of clams having 5 mg/kg of lead, one of lobster having 13 mg/kg of lead, and another of lobster containing 7 mg/kg of arsenic (as As_2O_3) the values for the remaining 120 samples analyzed were not significantly above limits established for heavy metal content of foods. Mean values of arsenic trioxide for all samples ranged from 0.10 to 1.33 mg/kg (range of individual values 0.0 to 7.0); for lead, mean values ranged from 0.33 to 0.83 mg/kg (individual values 0.0 to 13.0); for tin the means extended from 0.92 to 28.33 mg/kg (smoked oysters ranged from 25 to 30 mg/kg); for copper, means ranged from 2.4-37.7 with all values between 0.0 and 65 mg/kg; and finally mean iron values fell between 8.1 and 64.1 mg/kg (range of individual samples 0.0 in crabs to 110.0 for clams).

1526. Dimock, R.V., Jr., and K.H. Groves. 1975. Interaction of temperature and salinity on oxygen consumption of the estuarine crab *Panopeus herbstii*. Marine Biology 33:301-308.

Crabs were acclimated to all combinations of 10 and 23 C and 5 and 30^{o}/oo S. Rate of oxygen consumption was measured at 10 and 25 C in experimental salinities of 5, 15, 30 and 40^{o}/oo. Following acclimation to 23 C and 5^{o}/oo S, rate of oxygen consumption by females was significantly lower than males. No other experimental treatments resulted in significant rate differences between sexes. This suggests that warm-acclimated females, *i.e.* during reproductive periods, are excluded from areas of low salinity. Oxygen consumption increased on exposure to low salinity and low temperature, as well as to high salinity and high temperature. Unpredictable response patterns were elicited by specific experimental manipulations of temperature and salinity. Thermal sensitivity of oxygen uptake as reflected by Q_{10} was also influenced by experimental conditions and further substantiated occurrence of temperature-salinity interactions.

1527. D'Itri, F.M. 1972. Mercury in the aquatic ecosystem. Tech. Rep. No. 23, Inst. Water Res. Michigan State University, Lansing, Mich.: 101 pp.

Role of mercury in the aquatic environment is reviewed including introduction through industry, consumer products, and energy production. Abundance in marine, freshwater and terrestrial ores, rocks, waters, soils and sediments is examined. Biological aspects of Hg include biological methylation and other conversions, biological magnifications including pathways, mode of toxic action, and resultant implications to both freshwater and marine ecosystems. Taxa discussed include bacteria, fish, algae, mammals, birds, molluscs, crustacea, higher plants, insects, bryazoa, and annelids.

1528. Dobkin, S. and R.B. Manning. 1964. Osmoregulation in two species of *Palaemonetes* (Crustacea: Decapoda) from Florida. Bull. Mar. Sci. Gulf Caribb. 14:149-157.

The euryhaline shrimp *P. intermedius* maintained a constant osmotic concentration in salinities from 5 to 39°/oo. Blood of *P. paludosus*, a freshwater shrimp, was hypertonic in salinities up to 30°/oo. Regulation appeared to break down at salinities >20°/oo.

1529. Dodge, R.E. and J. Thomson. 1974. The natural radiochemical and growth records in contemporary hermatypic corals from the Atlantic and Caribbean. Earth Planetary Sci. Letters 23:313-322.

Skeletal banding was observed in vertical cross-sections of *Montastrea annularis* from Jamaica and *Diploria labrynthiformis* from Bermuda. This was confirmed to be annual by ingrowth of Th-228 towards radioactive equilibrium with Ra-228 taken up from seawater. *Diploria* has incorporated Pb-210 at a constant specific activity over the last 30 years.

1530. Donaldson, E.M. and H.M. Dye. 1975. Corticosteroid concentrations in sockeye salmon (*Oncorhynchus nerka*) exposed to low concentrations of copper. Jour. Fish. Res. Bd. Canada 32: 533-539.

Yearling salmon were exposed for 1-24 h to 0.00635, 0.0635, or 0.635 mg/l of copper (10^{-7}, 10^{-6}, or 10^{-5} M cupric sulphate, respectively). Cortisol, cortisone, and "total" corticosteroid levels were significantly higher than controls after exposure for one hour to 10^{-5} or 10^{-6} M copper. "Total" corticosteroid and cortisone concentrations were significantly higher than control concentrations after 2 and 4 h of exposure to 10^{-7} M copper, respectively. Fish exposed to 10^{-5} M copper died between 8 and 24 h. These data reflect a rapid corticosteroid stress response to lethal and sublethal concentrations of copper. The technique may be of use for rapid evaluation of effluents containing heavy metals, especially those containing a mixture of toxicants.

1531. Doolittle, R.F., C. Thomas and W. Stone, Jr. 1960. Osmotic pressure and aqueous humor formation in dogfish. Science 132:36-37.

Concentrations in mg/l of aqueous humor, and blood plasma, of dogfish Mustelus canis were 27 and 31 for K, 7 and 7 for Mg, 621 and 623 for Na, and 12 and 18 for Ca. Aqueous humor had a lower osmotic pressure than plasma by 25 milliosmoles.

1532. Dorigan, J.L. and K.M. Wilbur. 1973. Calcification and its inhibition in coccolithophorids. Jour. Phycol. 9:450-456.

The protein synthesis inhibitors cycloheximide and chloramphenicol, and transport inhibitors $LaCl_3$, oligomycin, and ethacrynic acid reversibly inhibit Ca uptake, coccolith formation, and cell division in the coccolithophorid Cricosphaera (Hymenomonas) carterae. With some compounds recovery of calcification was retarded, and in the case of oligomycin, incomplete. Glycerol at 0.5 M, partially reversed inhibitory effect of chloramphenicol on calcification but not on division. Ouabain was without significant effect on Ca uptake but slowed division in 3 of 5 experiments. Ruthenium red inhibited neither calcification nor division. In absence of light, calcification did not occur.

1533. Dorn, P. 1976. The feeding behavior of Mytilus edulis in the presence of methylmercury acetate. Bull. Environ. Contamin. Toxicol. 15:714-719.

Initial mean feeding rate (no Hg added) of mussels was 6,704 diatoms/mussel. At 0.4 mg/l methyl mercury, it was 659; at 0.8 mg/l methyl mercury, 181; and at 2.4 mg/l, 53 diatoms/mussel. Author suggests that decreased feeding may be result of neurological disruption in ciliary activity.

1534. Dove, G.R., O.W. Tiemier and C.W. Deyoe. 1976. Effects of three diets on growth and mineral retention of channel catfish fingerlings. Trans. Amer. Fish. Soc. 105:481-485.

Supplemental feeds containing different Ca and P compositions significantly affected whole-fish and lipid-free bone levels of Ca, P and Mg of fingerling catfish, Ictalurus punctatus. More dietary Ca and

P than supplied in supplemental feeds may be required during season of rapid growth.

1535. Dowden, B.F. and H.J. Bennett. 1965. Toxicity of selected chemicals to certain animals. Jour. Water Poll. Contr. Fed. 37(9):1308-1316.

LC-50 values during a 24 to 96 hour test period for 86 chemicals and combinations of chemicals, including Ca, Cr, Fe, Mg, and Zn were determined using representative freshwater species of amphipods, amphibians, fish, insects, planarians and snail (Lymnaea) eggs. Snail eggs had LC-50's comparable to those of adults of other forms due to protective egg case. LC-50 values for Ca ranged between 649 and 2573 mg/l at 96 h; for chromium compounds, values were 0.03 to 0.22 mg/l at 48 h; for iron, 15 mg/l at 96 h; for magnesium, 788 to 6250 mg/l at 96 h; and for zinc, 1 mg/l at 24 h.

1536. Doyle, M., S. Koepp and J. Klaunig. 1976. Acute toxicological response of the crayfish (Orconectes limosus) to mercury. Bull. Environ. Contamin. Toxicol. 16:422-424.

After exposure to $HgCl_2$ for 96 hrs, 93% survival was obtained by crayfish in 0.18 mg Hg/l, with little behavioral differences from controls. Survivors of the calculated LC-60 (0.74 mg/l Hg) were sluggish in response to mechanical stimulation. After 96 hrs only 15% survived 1.3 mg Hg/l, 8% at 1.8 mg Hg/l, and no survivors at 3.7 mg Hg/l. In general, decrease in percent survival was proportional to both time and toxicant concentration, with greatest number of deaths occurring between 24 and 72 hrs.

1537. Drifmeyer, J.E. 1974. Zn and Cu levels in the eastern oyster, Crassostrea virginica, from the lower James River. Jour. Wash. Acad. Sci. 64(4):292-294.

Shucked whole bodies of oysters contained up to 10,000 mg Zn/kg and 584 mg Cu/kg, with average values of 3915 mg Zn/kg and 180 mg Cu/kg. These levels are upper limits of values reported elsewhere and are considerably higher than levels reported in a previous survey of the same area. Data may indicate increased Zn contamination of lower James River oysters between 1971 and 1973.

1538. Duggan, W.P. 1975. Reactions of the bay scallop, Argopecten irradians, to gradual reductions in salinity. Chesapeake Sci. 16(4):284-286.

Scallops acclimated to salinity of 26°/oo at 10 to 15 C or 20 to 25 C showed measurable changes with decreasing salinity. Transition from a state of full extension of tentacles, gaped shells and occasional clapping of shells to full retraction of tentacles, closed shells and no shell clapping occurred over salinity range of 23 to 15°/oo.

1539. Dunstan, W.M., H.L. Windom and G.L. McIntire. 1975. The role of Spartina alterniflora in the flow of lead, cadmium and copper through the salt-marsh ecosystem. In: Howell, F.G., J.B. Gentry and M.H. Smith (eds.). Mineral Cycling in Southeastern Ecosystems. U.S. Energy Res. Dev. Admin.: 250-256. Available as CONF-740513 from NTIS, U.S. Dept. Comm., Springfield, VA 22161.

Mean metal levels of marsh grass Spartina from 6 southeastern U.S. rivers, in mg/kg, were 0.6 for Cd, 4 for Cu, and 5 for Pb. Spartina seedlings exposed to 100 mg/l levels of Cu and Pb showed growth inhibition in both cases, complete mortality after 2 weeks in Cu treatments, and 50% mortality after 8 weeks exposure to Pb. Exposure of seedlings for 8 weeks to 100 mg Cd/l did not affect growth although residues up to 94 mg Cd/kg were recorded. Authors conclude that this plant plays only a minor role in cycling of Cd, Cu and Pb in estuaries.

1540. Dunster, H.J., R.J. Garner, H. Howells and L.F.U. Wix. 1964. Environmental monitoring associated with the discharge of low activity radioactive waste from Windscale works to the Irish Sea. Health Physics 10(5):353-362.

Plaice Pleuronectes platessa, a marine flatfish, collected from the Windscale radioactive outfall region contained 0.77 to 4.2 pCi/g wet wt of Ru-106 and 0.017 to 0.056 pCi/g wet wt of Sr-90. Corresponding values for Porphyra umbilicalis, an edible seaweed, were 35 to 170 for Ru-106 and 0.04 to 0.14 for Sr-90. Mean activity levels, in pCi/g wet wt, of specific nuclides in bulked samples of edible seaweed were 0.038 to 0.13 for Sr-89, 0.023 to 0.29 for Sr-90, 54 to 221 for Ru-106, 1.0 to 4.8 for Y plus rare earths, 1.6 to 6.4 for Ce-144, 0.76 to 1.5 for Zr-95, 1.4 to 3.4 for Nb-95 and 0.04 to 1.5 for Cs-137.

1541. Edwards, R.R.C. 1967. Estimation of the respiratory rate of young plaice (Pleuronectes platessa L.) in natural conditions using zinc-65. Nature 216:1335-1337.

Rate of zinc-65 elimination is proposed as a means of studying respiratory rate of marine animals in natural habitat. For 0 group (less than 1 yr old) plaice at 16 C, loss of 35% of Zn-65 occurred in first 5 days after exposure after which elimination rate decreased; Zn-65 level stabilized in 43 days. Under various temperatures and feeding situations, Zn-65 levels measured from day 7 showed increased elimination with increased respiration.

1542. Eftekhari, M. 1975. Teneur en mercure de quelques crevettes du Golfe Persique. Science et Peche, Bull. Inst. Peches marit. 250:9-10.

Whole commercial shrimp from the Persian Gulf contained between 0.005 and 0.012 mg Hg per kg wet wt.

1543. Eganhouse, R.P., Jr. 1975. The measurement of total and organic mercury in marine sediments, organisms, and waters. So. Calif. Coastal Water Res. Project TM 221, 1500 E. Imperial Highway, El Segundo, Calif.: 25 pp.

Samples of Palos Verdes shelf sediment showed total Hg concentrations of 0.26 to 4.05 mg/kg dry wt; recovery of total, inorganic, and organic Hg from spiked sediment, water, orchard leaves, and tuna samples ranged from 77.2 to 106.4%. These methods appear useful for the routine measurement of mercury in marine samples.

1544. Ehrlich, H.L. 1976. Manganese as an energy source for bacteria. In: Nriagu, J.O. (ed.). Environmental Biogeochemisty. Vol. 2. Metals Transfer and Ecological Mass Balances. Ann Arbor Sci. Publ., Ann Arbor, Mich.: 633-644.

A gram-negative, motile, oxidase-positive rod isolated from ferromanganese nodules used Mn (II) oxidation to satisfy all or part of its energy requirements for assimilation of organic carbon. In a study of ATP-synthesis by a high-speed fraction of this culture, ratio of ATP synthesized to Mn removed from solution by enzyme catalysts (ATP/Mn) ranged from 0.032 to 0.101; the real efficiency may be up to 10x greater, as Mn assay measured total Mn absorbed including Mn oxidized. Of all Mn (II) concentrations tested, 0.004 M $MnSO_4$ had optimal effect on ATP production. Results suggest that at least 1 mole of ATP may be synthesized per mole Mn (II) oxidized, if synthesis were 100% efficient. Inhibitor studies imply that as many as 2 moles of ATP could be formed for each mole of MN (II) oxidized. Responses from inhibitor studies suggest an electron transport system by this bacterial strain in oxidizing Mn (II) including use of flavoproteins, cytochromes of b and c types and cytochrome oxidases.

1545. Eiben, R. 1976. Influence of wetting tension and ions upon settlement and beginning of metamorphosis in bryozoan larvae (Bowerbankia gracilis). Marine Biology 37:249-254. (In German, English abstract.)

Contractions which initiate metamorphosis, and metamorphosis itself, were induced in free swimming larvae of B. gracilis by application of CsCl or KCl; $MgCl_2$ prevents onset of metamorphosis but not adhesion.

1546. Eisler, R. and G.W. Kissil. 1975. Toxicities of crude oils and oil-dispersant mixtures to juvenile rabbitfish, Siganus rivulatus. Trans. Amer. Fish. Soc. 104:571-578.

Juvenile rabbitfish are strongly euryhaline, and can withstand without apparent deleterious effect abrupt transplantation from $20^{o}/oo$ seawater (after a residence time of 7 days) to $60^{o}/oo$ for at least 8 days, and vice versa. Rabbitfish survival at a given petrochemical concentration was highest at intermediate salinities of $30\text{-}50^{o}/oo$ in the salinity range tested of 20 to $60^{o}/oo$.

1547. Eisler, R. and M. Wapner. 1975. Second annotated bibliography on biological effects of metals in aquatic environments. (No. 568-1292). U.S. Environ. Protect. Agen. Rept. EPA-600/3-75-008: 400 pp. Avail. from Nat. Tech. Inform. Serv., Springfield, VA 21161.

A total of 725 references are listed on the toxicological, physiological, and metabolic influence of stable and radiolabelled chemical species of metal cations to marine, estuarine, and freshwater fauna and flora. References were annotated and subsequently indexed by metal, by taxa, and by author, in cumulative indices which encompassed this volume and the initial volume in the series (Eisler, R. 1973. Annotated bibliography on biological effects of metals in aquatic environments [No. 1-567]. U.S. Envir. Prot. Agen. Rept. R3-73-007: 287 pp.).

1548. Elder, J.F., K.E. Osborn and C.R. Goldman. 1976. Iron transport in a Lake Tahoe tributary and its potential influence upon phytoplankton growth. Water Research 10:783-787.

Iron concentrations of water from Ward Creek, a tributary of Lake Tahoe, showed marked seasonal variability. Total Fe transport during a one-year period in 1972-73 was approximately 6000 kg, or 0.2% of total Fe content of Lake Tahoe. Most Fe in stream water of Lake

Tahoe basin results from erosion, producing a high predominance of particulate forms. Because of possibility of various breakdown mechanisms, this Fe is potentially stimulatory to lake algal growth.

1549. Elderfield, H., L. Thornton and J.S. Webb. 1971. Heavy metals and oyster culture in Wales. Marine Poll. Bull. 2:44-47.

Zinc, lead and copper in water and particulate matter (>0.45 μ) were measured over a period of one year in the Conway Estuary, North Wales to establish causality between levels and poor larval productivity in a local oyster hatchery. Zinc and Pb of water and particulate matter were highest in February and lowest in June. Zinc content in February was 264 mg/kg and 9.0 μg/l for particulate matter and water, respectively, and 64 mg/kg and 2.4 μg/l in June. Lead content was 89 mg/kg and 2.9 μg/l for particulate matter and water, respectively, in February and 21 mg/kg and 0.8 μg/l in June. Maximum Cu content in particulate matter was 91 mg/kg in January and 2.8 μg/l for water in February. Minimum Cu content of particulate matter was 56 mg/kg in March and 2.2 μg/l for water which occurred in April. Preliminary experiments have shown that Zn at concentrations of less than 100 μg Zn/l, had minimal effects; at 300 μg/l larval growth rate was considerably reduced and at 500 μg/l larvae either died or failed to metamorphose.

1550. Ellis, M.M. 1934. Arsenic storage in game fish. Copeia 1939 (2):97.

Two of seven gamefish collected from the Yellowstone River contained measurable levels of arsenic (2.4-2.7 mg/kg wet wt) in their musculature. Author suggests that trout and whitefish had stored arsenic cumulatively from stone-fly nymphs taken as food, and not from the water. During the past 10 years several sportsmen and others have reported sudden violent illness suggestive of arsenic poisoning following meals including game fish caught in this part of the Yellowstone.

1551. Ellis, M.M., H.L. Motley, M.D. Ellis and R.O. Jones. 1937. Selenium poisoning in fishes. Proc. Soc. Exp. Biol. Med. 36:519-522.

Exposure of goldfish to 2 mg Se/l resulted in death in 18 to 46 days, preceded by equilibrium loss and lethargy. Death occurred in 4 to 10 days upon exposure to 5 mg Se/l. Intraperitoneal injection of a 0.5% solution of sodium selenite into catfish Ictalurus punctatus in the amount of 3 mg Se/kg fish was fatal in <48 hr at 10 C. Increased temperature increased Se toxicity. Symptoms of acute Se poisoning included contraction of dermal chromatophores, loss of coordination and muscle spasms. Delayed symptoms produced by lower doses and occurring after 7 days included protrusion of eyes, pendulous abdomen and degeneration of liver about central veins. Blood contained less hemoglobin, fewer red blood cells, and more white blood cells than controls.

1552. Ellis, M.M., B.A. Westfall and M.D. Ellis. 1941. Arsenic in freshwater fish. Indust. Engineer. Chem. 35:1331-1332.

Arsenic, as the trioxide, was determined in 15 species of freshwater teleosts collected from inland waters of Florida, Georgia, Alabama, and Texas. Maximum concentrations recorded on a wet wt basis ranged from 0.5 to 2.7 mg/kg. On a dry wt basis this was 1.7 to 14.2 mg/kg. The maximum values recorded for fish oil ranged from 2.8 to 160.7 mg/kg. Values for oil were similar to those reported for marine macrofauna. Arsenic analyses of freshwater crustaceans ranged from 3.2 to 5.4 mg/kg on a dry wt basis and from 4.6 to 25.4 mg/kg in oil. Author suggests there is ample arsenic in these crustacea which are regularly eaten by freshwater fishes to supply the arsenic found in fish oils.

1553. Elroi, D. and B. Komarovsky. 1961. On the possible use of the fouling ascidian Ciona intestinalis as a source of vanadium, cellulose and other products. Proc. gen. Fish. Coun. Medit. 6:261-267.

Tunicates, growing on rafts in Haifa and Kishon harbors, Israel, contained between 0.04 and 0.7% vanadium on an ash weight basis. Figures obtained confirm published data as to high content of V in ascidians in general and in Ciona intestinalis in particular.

1554. Elson, P.F. 1974. Impact of recent economic growth and industrial development on the ecology of Northwest Miramichi Atlantic salmon (Salmo salar). Jour. Fish. Res. Bd. Canada 31:521-544.

The history of salmon runs of the Miramichi from 1950 to 1973 is reviewed. Decreases are related to degrading of ecological conditions in the river's rearing reaches due to adverse chemical conditions attributable to recent developments in forest management and mining of Cu and Zn. Diversion of indigenous adult stocks into other streams, and loss of rearing ground because of home stream pollution by mining, pulp mill, and other human activities are examined. Increase of commercial catches as a result of pollution-caused delay in the estuary of migrating adults is analyzed. Grave depletion of stocks due to combined effects of these factors plus distant-water fishing is identified, as is incipient recovery of stocks when home-water commercial fishing was eliminated and pollution abatement measures introduced. A suppressing effect of heavy angling pressure on stock abundance when stocks are low is noted.

1555. Elson, P.F., A.L. Meister, J.W. Saunders, R.L. Saunders, J.B. Sprague and V. Zitko. 1973. Impact of chemical pollution on Atlantic salmon in North America. Int. Atlantic Salmon Symp., St. Andrews, New Brunswick 6:83-110.

Effects of pesticides, industrial and agricultural chemical wastes including polychlorinated biphenyls, pentachlorophenol, oils, agricultural runoff, industrial and municipal effluents and heavy metals on Atlantic salmon populations are listed.

In a study of the Northwest Miramichi River, lethal thresholds of 48 μg Cu/l (=1 toxic unit) or 600 μg Zn/l (=1 toxic unit) were found for salmon parr. In combination, deleterious effects of the two metals was additive. In the laboratory, parr avoided Cu-Zn solutions of 0.02 toxic unit concentrations. In field studies 0.35 to 0.43 toxic unit was required before avoidance and fall back of upward-moving salmon occurred. At 0.8 toxic unit, upstream migration was completely blocked. Death, due to extensive lesions associated with epidemic bacterial infection, was ascribed to a previous heavy surge of Cu-Zn pollution. Alteration of previous migration patterns was also noted. New Brunswick surface waters contain significant amounts of humic materials, which decrease the acute toxicity of Cu but not Zn ions. Mercury levels in both juvenile and adult salmon are $\sim$0.1 mg/kg, present as methyl-Hg.

1556. Elvehjem, C.A. 1935. The biological significance of copper and its relation to iron metabolism. Physiol. Rev. 15:471-507.

Concentrations of copper in marine molluscs, in combination with blood hemocyanin, were, in mg/l: *Octopus vulgaris* 180 to 235; *Sepia officinalis* 237; and *Helix pomatia* (gastropod) 65 to 125. For crustaceans these were: *Astacus fluviatilis* 70; *Palinurus vulgaris* 95; *Homarus vulgaris* 100; *Cancer pagurus* 60; *Carcinus maenas* 90; *Maia squinado* 35; and *Squilla mantis* 61. Copper was present in all fish studied, except pigfish, at an average of 2.5 mg/kg; clams had little or none; oysters 24 to 60 mg/kg; shrimps and crabs varied between 2.5 and 24, primarily in exoskeleton; jellyfish (*Aurelia*) and Portuguese man-of-war (*Physalia*) were about equal in copper content to fish, on a wet basis. Whale tissue and sea lion blood had no detectable copper, but muscle, liver, spleen, and bile of sea lion contained trace amounts. The respiratory capacity of blood and oxygen:Cu ratios are discussed;

presence of Zn in blood of *Busycon canaliculatum* and *B. carica* (gastropods) and vanadium in blood of *Ascidians* is noted.

Copper is also discussed as an element in the avian pigment turacin, as an iron supplement in hemoglobin formation, as a nutritional supplement and as a requirement for growth of higher plants, yeasts, and some microorganisms. The toxic effect of Cu is mentioned briefly: rats receiving 527 mg/kg Cu from "green oysters" or $CuSO_4$ (7 x human consumption rate, at one serving/day) were unaffected.

1557. Elwood, J.W. and L.D. Eyman. 1976. Test of a model for predicting the body burden of trace contaminants in aquatic consumers. Jour. Fish. Res. Bd. Canada 33:1162-1166.

Model parameters were determined in a single-feeding experiment using bluegill, *Lepomis macrochirus*, and food labeled with Cs-137. Independent of this single-feeding experiment, bluegill were allowed to ingest Cs-137 contaminated food over a 16-day period; afterwards the predicted and measured body burden of radionuclide were compared. Model realistically simulated absorption of Cs-137 from gastrointestinal tract and its accumulation over 16-day period. Average body burden of Cs-137 in fish was within 25% of predicted body burden when experiment was terminated. Apparent equilibrium of Cs-137 in bluegill by day 16 suggests that this two-compartment linear model does not apply to long-term accumulation of cesium in fish. The model appears most applicable for predicting body burdens of trace contaminants under acute exposure conditions that simulate an accidental release.

1558. Elwood, J.W., S.G. Hildebrand and J.J. Beauchamp. 1976. Contribution of gut contents to the concentration and body burden of elements in *Tipula* spp. from a spring-fed stream. Jour. Fish. Res. Bd. Canada 33:1930-1938.

Larvae of *Tipula* spp., a detritus-feeding aquatic insect, collected from an unpolluted stream were analyzed for Na, K, Rb, Cs, Ca, Ba, Zr, Th, V, Ta, Cr, Mn, Fe, Co, Zn, Hg, Al, Se, Sc, La, Ce, Nd, Eu, and other elements before and after gut evacuation to determine contribution of gut contents to whole-body concentrations. Chromium and Al concentrations were inversely related to body size, suggesting surface contamination. All elements analyzed except Na, Cr, Hg, Zn, and Se were significantly lower in concentration after gut evacuation (18% decrease for K to approximately 70% for V, Mn, Hf, and some of the rare earths). Ratios of variances of mean concentrations in organisms with guts filled to those with guts evacuated indicate that gut contamination is a major source of variation in measured whole-body concentrations of many elements. Calculated percentage of element body burden associated with gut contents ranged from <1% for Na to 89% for Zr, with a mean for all elements analyzed of 57 ± 8%. Calculated trophic transfer factors (TTF = element concentration in larvae with guts evacuated/concentration in leaf detritus) for elements which are obtained primarily through the food chain were significantly >1 only for Zn; TTFs for all other elements were <1.

1559. Engel, D.W. and J.W. Angelovic. 1968. The influence of salinity and temperature upon the respiration of brine shrimp nauplii. Comp. Biochem. Physiol. 26:749-752.

Respiration rates of day old nauplii of *Artemia salina* decreased with increasing salinity at all five temperatures tested (10, 15, 20, 25, and 30 C). The change in Q_{10} value (respiration rate) per unit change in temperature decreased with increasing salinity (0.89 at 5^{o}/oo, 0.76 at 50^{o}/oo, 0.77 at 100^{o}/oo, 0.54 at 150^{o}/oo, and 0.43 at 200^{o}/oo). Q_{10} values were significantly affected by temperature at the 0.01 probability level; however, salinity and temperature-salinity interactions were not statistically significant at the .05 level and lower.

1560. Epstein, F.M., A.I. Katz and G.E. Pickford. 1967. Sodium- and potassium-activated adenosine triphosphatase of gills: role in adaptation of teleosts to salt water. Science 156:1245-1247.

Activity of Na^+- and K^+-activated ATPases was higher in gill and pseudobranch of killifish, *Fundulus heteroclitus*, adapted to salinity of 26^{o}/oo than those adapted to freshwater. Hypophysectomy reduced ATPase activity in gills. Authors suggest that this enzyme is involved in Na^+ excretion by gills and that adaptive increase which occurs in seawater is influenced by hypophysis.

1561. Establier, R. 1975. Concentracion de mercurio en los cabellos de la poblacion de Cadiz y pescadores de altura. Investigacion Pesquera 39(2):509-516. (In Spanish, English summary.)

Hair of Cadiz city inhabitants contained 0.7 to 8.0 mg Hg/kg, with a mean of 4.0 mg Hg/kg. Fishermen had 10.3 to 45.4 mg Hg/kg hair, with a mean of 19.8 mg Hg/kg. Hg content of an infant's hair fell from 17.5 to 3.5 mg Hg/kg in 2 years after removal of sword fish *Xiphias gladius* from diet. Fishermen showed no definite symptoms of methyl-Hg poisoning.

1562. Establier, R. 1975. Contenido en mercurio de las anguilas (*Anguilla anguilla*) de la desembocadura del río Guadaliquivir y esteros de las salinas de la zona de Cadiz. Investigacion Pesquera 39(1):249-255. (In Spanish, English summary.)

Eels from the Guadalquivir River estuary and environs contained between 0.19 and 0.27 mg total Hg/kg wet wt. Mullet, *Mugil cephalus* and *M. aurata*, contained <0.12 mg Hg/kg wet wt. Sedimentary Hg levels from intertidal areas of Cadiz Bay ranged between 0.12 and 0.18 mg/kg.

1563. Etges, F.J. 1963. Effects of some molluscicidal chemicals on chemokinesis in *Australorbis glabratus*. Amer. Jour. Trop. Med. Hyg. 12:701-704.

Snails, *A. glabratus*, were repelled by sublethal concentrations of 0.01 and 0.256 µg/l of $CuSO_4$ and $ZnCl_2$, respectively. ZnO, $BaCO_3$, $BaCl_2$, $Co(NO_3)_2$ and $SnCl_2$ at levels of 80 mg/l, did not repel snails. LC-50 (140 hr) level for ZnO was 100 mg/l; egg production was inhibited by 10 mg ZnO/l.

1564. Eustace, I.J. 1974. Zinc, cadmium, copper and manganese in species of finfish and shellfish caught in the Derwent Estuary, Tasmania. Austral. Jour. Mar. Freshwat. Res. 25: 209-220.

In the 7 species of elasmobranchs studied, highest concentrations (and range of median values) of Zn, Cd, Cu, and Mn, in mg/kg wet wt, were: 9.6 (4.6 to 5.0), 0.3 (<0.05), 4.3 (<0.25 to 0.7), and 1.6 (<0.5), respectively. The one species of Holocephalan examined (*Callorynchus millii*) contained up to 6.7 Zn (median 5.0), <0.05 Cd, 3.6 Cu (median 0.4), and 0.6 Mn (median <0.5). Twenty-three species of finfish were analyzed and highest concentration found were: 146.7 Zn (median 5.0 to 13.5), 0.3 Cd (median <0.05 to 0.06), 14.4 Cu (median 0.5 to 2.1), and 15.0 Mn (median <0.5 to 1.3). Eight species of invertebrates were analyzed; levels of Zn, Cd, Cu, and Mn (in mg/kg) found in each, respectively, were: *Ostrea angasi* (oyster) 5,657.0, 10.7, 57.9, 2.5; *Mytilus edulis* (mussel) 45.8, 5.5, 3.1, 2.5; *Notodarius gouldi* (squid) 18.5, <0.05, 5.3, <0.5; *Octopus* sp. 18.5, <0.05, 7.0, 0.6; *Clibanarius strigimanus* (hermit crab) 74.3, <0.05, 15.8, 0.8; *Patiriella regularis* (mud starfish) 245.0, 0.7, 31.4, 51.7; *Coscinasterias calamaria* (red starfish) 40.6, 0.6, 10.4, 6.9; and *Ascidiacea* sp. (tunicate) 64.0, 0.2, 8.3, 112.6.

Differences in levels of Zn and Cu in fish muscles are attributed to different feeding habits. No abnormal levels of heavy metals were found in fish. With minor exceptions no relationships exist between tissue metal content and length of fish. Molluscs, particularly the edible species of oysters and mussels, accumulated much higher levels of metals than fish, Zn and Cd exceeding levels specified by food regulations (40 mg/kg Zn, 5.5 mg/kg Cd, 30 mg/kg Cu) in both species. Since elevated metal concentrations in seawater are not reflected in muscle tissues of finfish, the monitoring of commercial fish species caught in the River Derwent provides a much less sensitive index of pollution than would monitoring of oysters or mussels.

1565. Evans, D.H., C.H. Mallery and L. Kravitz. 1973. Sodium extrusion by a fish acclimated to sea water: physiological and biochemical description of a Na-for-K exchange system. Jour. Exp. Biol. 58:627-636.

Na^+ extrusion by *Dormitator maculatus* acclimated to seawater is coupled with K uptake and mediated by enzyme Na-K-activated ATPase.

1566. Evans, D.H., J.C. Carrier and M.B. Bogan. 1974. The effect of external potassium ions on the electrical potential measured across the gills of the teleost, *Dormitator maculatus*. Jour. Exp. Biol. 61:277-283.

Transfer of fish to various KCl solutions is correlated with changes in transgill potential (TGP), which are insufficient to account for known K stimulation of Na efflux. Transfer to K-free seawater results in negligible change in TGP while previous results have shown that such a transfer is correlated with a 22% reduction of Na efflux. Transfer to fresh water results in a reduction of TGP and this is sufficient to account for instantaneous reduction in Na efflux. While changes in TGP can account for the "Na-free effect," they cannot account for K effects on Na extrusion. Authors suggest that Na efflux and K influx are chemically linked.

1567. Evans, D.H., K. Cooper and M.B. Bogan. 1976. Sodium extrusion by the seawater-acclimated fiddler crab *Uca pugilator*: comparison with other marine crustacea and marine teleost fish. Jour. Exp. Biol. 64:203-219.

Total body and haemolymph Na contents of *Uca* in seawater were 5.0 and 10.4 g/kg. Blood Na concentration and transepithelial electrical potential (T.E.P.) across *U. pugilator* acclimated to seawater indicate that Na is maintained out of electrochemical equilibrium with seawater. Resulting net Na influx as well as Na gain due to ingestion of the medium must be balanced by extrarenal Na extrusion. The small T.E.P.

and "transport numbers" of Na and Cl indicated that permeability to these ions is equivalent. Removal of external K results in a significant stimulation of unidirectional Na efflux that is dependent upon external Na but is not inhibited by ouabain.

Transfer of *Uca* to K and Na-free seawater results in a 54% decline in unidirectional efflux, which is not due to T.E.P. changes. Readdition of 975 mg K/l stimulates Na efflux much more than can be accounted for by changes in the T.E.P. Readdition of 575 mg Na/l to K-free seawater does not change Na efflux. Results indicate that Na extrusion by *Uca* is via a Na/K exchange mechanism which partially inhibits Na/Na exchange. Cessation of Na/K exchange (in K-free seawater) removes this inhibition and allows rapid Na/Na exchange. It is not known whether Na/K and Na/Na exchange are via the same or parallel carrier systems.

1568. Fagerström, T., R. Kurten, and B. Asell. 1975. Statistical parameters as criteria in model evaluation: kinetics of mercury accumulation in pike *Esox lucius*. Oikos 26:109-116.

Some processes involved in mercury accumulation by individual fish were studied using computer simulations. In general, temporal variations of processes at the individual level are reflected in population statistical parameters. Hg uptake rate per unit weight probably covaries with body weight. This conclusion is derived from a qualitative analysis approach where correlation, within age classes, between body weight and Hg concentration proves useful. This correlation may be more informative than the correlation calculated without accounting for age.

1569. Fänge, R., U. Lidman, and A. Larsson. 1976. Comparative studies of inorganic substances in the blood of fishes from the Scagerac Sea. Jour. Fish Biol. 8:441-448.

Main plasma inorganic electrolyte concentrations were determined for several orders of marine fishes. Mean concentrations were 462 mM for the cyclostome, *Myxine glutinosa*, 317 mM for the holocephalan, *Chimaera monstrosa*, from 234 to 282 mM for elasmobranchs and from 162 to 198 mM for teleosts. Mean K^+ concentrations were 9.0 mM for *M. glutinosa*, 7.9 mM for *C. monstrosa*, from 3.9 to 5.4 mM for elasmobranchs, and from 3.9 to 8.0 mM for teleosts. Mean Ca^{2+} concentrations were 6.3 mM for *M. glutinosa*, 4.3 mM for *C. monstrosa*, from 3.4 to 4.5 mM for elasmobranchs, and from 1.8 to 4.5 mM for teleosts. Mean Mg^{2+} concentrations were 10.1 mM for *M. glutinosa*, 3.8 mM for *C. monstrosa*, from 1.3 to 2.2 mM for elasmobranchs, and from 0.7 to 5.3 mM for teleosts.

1570. Federighi, H. 1931. Salinity death-points of the oyster drill snail, Urosalpinx cinerea Say. Ecology 12:346-353.

Oyster drills collected from areas in Hampton Roads, Virginia, where the summer salinity was 15 and 20^{o}/oo, had salinity death-points of 12.5 and 11.7^{o}/oo. Snails collected at Beaufort, North Carolina, where environmental salinity is >30^{o}/oo, showed lethal salinities of 15.6 and 17.6^{o}/oo. Author concludes that environmental salinity influences death point salinity, although the relation is not directly proportional, since, as the animal becomes adapted to lower salinities, the salinity factor of safety (difference between average environmental salinity and death point salinity) becomes smaller.

1571. Filip, D.S. and R.I. Lynn. 1972. Mercury accumulation by the freshwater alga, Selenastrum capricornutum. Chemosphere 6: 251-254.

Using test concentrations of 0.1 mg Hg/l, Hg uptake by live algal cells either in light or dark, was not significantly higher than uptake by killed cells. Therefore, the mechanism of Hg uptake appears to be solely of a passive absorptive nature. Since both living and dead cells rapidly absorb dissolved inorganic mercury, even at very low concentrations, this algae should be considered as a possible point of entry of Hg into the aquatic food web at the lowest trophic level.

1572. Finesinger, J.E. 1926. Effect of certain chemical and physical agents on fecundity and length of life and on their inheritance in a rotifer, Lecane (Distyla) inermis (Bryce). Jour. Exp. Zool. 44:63-96.

In pure springwater, parthenogenetic rotifers increased egg production when 0.63 to 2.5 mg $FeSO_4$/l was added. Addition of 4.5 and 0.45 mg $FeCl_3$/l decreased egg production over a 12 week period; lifespan was not affected by Fe additions. No adverse effects were evident after exposure to 0.45 mg $FeCl_3$/l treatment in first generation after return to normal. However, effects of 4.5 mg $FeCl_3$/l treatment were retained for two generations.

1573. Fingal, W. and H.W. Kaplan. 1963. Susceptibility of Xenopus laevis to copper sulfate. Copeia (1963)1:155-156.

Female toads X. laevis were placed in semidarkness at 22 C in dechlorinated tap water and varying concentration of copper sulphate solution. In 30-day experiments, no mortalities occurred in concentrations up to 0.1 mg/l of Cu^{2+}. In 0.15 mg Cu^{2+}/l, mortalities first occurred on day 6 with total mortality by day 15. In 0.25 and 0.5 mg

Cu^{2+}/1 deaths occurred on the first day, with all dead by day 9. At 2.5 and 10.0 mg Cu^{2+}/1, all toads died on the first day. For all toxic Cu^{2+} concentrations, output of mucous increased markedly over whole body surface; eyes appeared especially irritated. In low concentrations, heart rate first increased then decreased; in toxic concentrations, rate progressively dropped to subnormal levels, and in some cases became arhythmic. Neuromuscular coordination was disturbed, general activity decreased, and postural reflexes disappeared in terminal days; skin peeled off in immersed body areas.

1574. Finkle, B.J. and D. Appleman. 1953. The effect of magnesium concentration on growth of Chlorella. Plant Physiol. 28:664-673.

In 49 mg Mg/1, cell populations of algae C. vulgaris increased and synthesis of cell material proceeded rapidly without Mg limitation. Cells decreased greatly in size during rapid growth and remained small. Symptoms of Mg deficiency appeared in cultures initially containing <1.0 mg Mg/1, while only some of these deficiency effects were apparent in cultures with 2.8 mg Mg/1. Mg deficiency interrupted multiplication at cell population sizes proportional to original Mg concentrations. Cell material synthesis was not arrested; cell size increased greatly, some cultures deficient in Mg produced cells that were more than 20X larger than controls. Increases in cell size were paralleled by proportional increases in nitrogen content and dry weight. It was concluded that multiplication requires a larger concentration of Mg than does production of cell material. Anatomical observations suggest that cell division was taking place in Mg deficient cultures but this was not apparent owing to lack of cell separation.

1575. Finley, M.T., M.P. Dieter and L.N. Locke. 1976. Lead in tissues of mallard ducks dosed with two types of lead shot. Bull. Environ. Contamin. Toxicol. 16:261-269.

Mallards Anas platyrhynchos pen-reared for 6 months were sacrificed one month after ingesting one number 4 all-lead shot or one number 4 lead-iron shot containing 47.5% lead. Necropsy of sacrificed ducks showed no tissue lesions usually associated with lead poisoning in waterfowl. Lead levels in ducks given all-lead shot averaged about twice those in ducks given lead-iron shot, reflecting amount of lead in the two types of shot. Lead in blood of ducks dosed with all-lead shot averaged 0.64 mg/1; and for ducks given lead-iron shot this was 0.28 mg/1. Lead residues in livers and kidneys of females given all-lead shot were significantly higher than males. In both dosed groups, lead levels in wingbones of females were 10 times those in males, and were significantly correlated with number of eggs laid after dosage. Lead levels in contents and shells of eggs laid by hens dosed with all-lead shot were twice those in eggs laid by hens dosed with lead-iron shot. Eggshells best reflected levels of lead in blood. Authors conclude that mallards maintained on a balanced diet and dosed with one lead shot may not accumulate extremely high lead levels in liver and kidney. But extremely high lead deposition may result in bone of laying hens after ingesting sublethal amounts of lead shot as a result of mobilization of calcium from bone during eggshell formation.

1576. Fleming, W.R., J. Nichols and W.T.W. Potts. 1974. The effect of low-calcium seawater and actinomycin-D on the sodium metabolism of *Fundulus kansae*. Jour. Exp. Biol. 60:267-273.

Transfer of *F. kansae* from 80% sea water to a low-calcium water containing 16 mg Ca^{++}/ℓ resulted in a sharp rise of sodium efflux producing a transient drop in whole-body Na levels within 1 to 2 days. Both Na and K levels were normal after 9 days exposure to low-Ca media. Exposure to low-Ca water significantly increased rates of radiophosphorus incorporation into gill RNA. Actinomycin-D blocked stimulation of Na turnover after transfer into low-Ca sea water, but did not affect whole-body Na or K levels of long-term sea-water adapted animals. Actinomycin-D reduced Na efflux of short-term sea-water adapted animals regardless of environmental Ca concentration, and upset the balance of Na fluxes in those animals held in low-Ca sea water. Authors suggest that in addition to effect of Ca on permeability to monovalent ions and water, Ca inhibits synthetic processes regulating Na metabolism and stabilizes metabolic processes already present.

1577. Fletcher, G.L., E.G. Watts, and M.J. King. 1975. Copper, zinc, and total protein levels in the plasma of sockeye salmon (*Oncorhynchus nerka*) during their spawning migration. Jour. Fish. Res. Bd. Canada 31:78-82.

Copper concentrations in blood plasma decreased from about 1.4 to about 0.5 mg/l for salmon migrating to the Chilko spawning ground, British Columbia, in 1971. Loss occurred primarily during spawning. Zinc content dropped from about 0.23 to 0.05 mg/l, mostly during the transition from seawater to freshwater. Copper:plasma protein ratios remained constant, but zinc:protein ratios decreased, indicating independent removal mechanisms.

1578. Floch, H., R. Deschiens and Y. Le Corroller. 1964. Sur l'action molluscicide élective de l'oxyde cuivreux du cuivre métal et du chlorure cuivreux. Bull. Soc. Pathol. Exotique 57(1):124-138.

Lethality of various copper salts was determined using gastropod vectors of bilharziosis (Australorbis glabratus, Bulinus contortus and Lymnea stagnalis) and non-target organisms including teleosts, crustaceans, aquatic insect larvae, and aquatic plants. In general gastropods were more sensitive to copper compounds than other groups tested. Colloidal copper was most effective, killing all gastropod vectors at 0.075 mg Cu/l in 3-5 days.

1579. Foster, P. 1976. Concentrations and concentration factors of heavy metals in brown algae. Environ. Pollut. 10:45-53.

Samples of Fucus vesiculosus from the Menai Straits had mean concentrations (in mg/kg) of 116 for Zn, 9 for Cu, 103 for Mn, 8 for Ni, 218 for Fe, 2 for Cd, 3 for Pb, and 4 for Cr; Ascophyllum nodosum contained 149 Zn, 12 Cu, 21 Mn, 5 Ni, 86 Fe, 2 Cd, 2 Pb, and 3 Cr. The concentration factors (in mg/kg dried seaweed per ug/ml dissolved metal in seawater) from this and previous studies were found to be: 1.3×10^4 for Zn, 8.6×10^3 for Cu, 3.9×10^3 for Mn, and 4.6×10^3 for Ni in Ascophyllum; and 1.0×10^4 to 6.4×10^4 for Zn, 3.7×10^3 to 2.7×10^4 for Cu, 4.6×10^3 to 2.6×10^4 for Mn, and 2.8×10^3 to 6.8×10^3 for Ni in Fucus. When samples were analyzed from the mouth of Dulas Bay, an area of high metal pollution, levels (in mg/kg) increased in Fucus to: 306 Zn, 71 Cu, 71 Mn, 6 Ni, and 75 Fe; and in Ascophyllum to: 199 Zn, 68 Cu, 16 Mn, 5 Ni, and 30 Fe. Both species of algae can be used as environmental indicators of Cu, and Fucus can be used for Zn. Neither species showed direct relationships between concentrations of Fe and Mn in the weeds and water. Concentrations of Cd, Pb, and Cr were less for seaweeds in Dulas Bay, contrary to the higher levels of these metals in the water; in Fucus, concentrations were 1.8, 2.3, and 3.8, respectively, and in Ascophyllum, 1.5, 2.2, and 2.2, respectively. This suggests that in highly polluted areas algal concentrations of minor elements do not reflect water concentrations.

1580. Fowler, B.A., D.A. Wolfe, and W.F. Hettler. 1975. Mercury and iron uptake by cytosomes in mantle epithelial cells of quahog clams (Mercenaria mercenaria) exposed to mercury. Jour. Fish. Res. Bd. Canada 32:1767-1775.

Mercury increased and Fe decreased in mantle fringes of clams exposed to 0, 0.1, 1, and 10 mg Hg^{2+}/l. After 6 days Hg and Fe contents in mg/kg wet wt were respectively 0.90 and 16.7 (controls), 2.0 and 9.6 (0.1 mg Hg^{2+}/l), 3.9 and 6.0 (1 mg Hg^{2+}/l) and 6.6 and 15.3 (10 mg Hg^{2+}/l). A dose-related increase of electron dense cytosomes was observed by electron microscopy in mantle tentacle epithelial cells of Hg-treated clams.

1581. Fowler, J.R. 1931. The relation of numbers of animals to survival in toxic concentrations of electrolytes. Physiol. Zool. 4:215-245.

In 20 ml of solution, single Daphnia longispina exhibited greater survival than groups of 20 individuals at electrolyte levels, in g/l, of 4.13 for $CaCl_2$, 1.85 for KCl, 3.5 for $MgCl_2$, 32.4 for $MgSO_4$, 4.9 for $Ca(NO_3)_2$, 0.19 for $Zn(NO_3)_2$, 6.38 for $NaNO_3$, 2.9 for NaCl, 0.024 for NaOH, and 0.0084 for KOH. Groups of 20 individuals were favored in higher metal solutions, in g/l, of 7.15 for $CaCl_2$, 3.7 for KCl, 4.7 for $MgCl_2$, 43.2 for $MgSO_4$, 8.2 for $Ca(NO_3)_2$, 2.8 for $Zn(NO_3)_2$, 11.5 for $NaNO_3$, 8.7 for NaCl, 0.2 for NaOH, and 0.14 for KOH. Introduction of CO_2 into toxic solutions with Daphnia increased their survival time in strong concentrations and decreased their survival time in weak concentrations. Author concluded that CO_2 is an important factor in causing differential survival between groups of Daphnia and single individuals when exposed to toxic solutions.

1582. Fowler, S.W. 1966. Uptake and retention of zinc-65 by Euphausia pacifica Hansen. M.A. Thesis. Oregon State University, Corvallis, Oregon: 58 pp.

Uptake, retention and desorption of Zn-65 by live and formalin-preserved E. pacifica were observed at 5, 10 and 15 C and at concentrations of 10 and 25 μc Zn-65/l. There was proportionately more weight-specific uptake of Zn-65 at 25 μc Zn-65/l than at 10 μc/l. Uptake in live animals was dependent upon water temperature, size of animal, and concentration of Zn-65 in water. Weight-specific uptake was linear over the 5-15 C range, with uptake lowest at 5 C and highest at 15 C. Weight-specific uptake and concentration factors (ratios of cpm/g dry weight to cpm/ml water), corrected to 44 hours, generally decreased as weight increased, particularly at 5 and 10 C. There was a general similarity of concentration factors at 10 and 25 μc/l for animals of similar weight at any given temperature; a temperature dependency was noted with lowest concentration at 5 C and highest at 15 C. Loss rates were dependent upon initial Zn-65 concentration in euphausiids, with greatest loss in animals with the highest specific activity (cpm/mg). Loss rates were weight dependent, and also temperature dependent, with greater loss at higher temperatures. Considering losses of activity due to moulting during uptake (34%) and during desorption (17%), a realistic figure for loss of Zn-65 through moulting averaged about 25% of total body activity. Since weight-specific uptake and loss of Zn-65 was dependent upon weight (perhaps surface area) and concentration of isotope, and since similar responses to Zn-65 uptake and loss were achieved with formalin-preserved euphausiids as well as live ones, it was concluded that Zn-65 accumulation by euphausiids was an adsorptive process, and that temperature increases might somehow alter exoskelton constituents so as to present additional sorption sites.

Concentration factors computed from field data were 7 to 24 times greater than those from laboratory data. Although several factors tended to show that the data were not comparable, the possibility existed that euphausiids could accumulate more Zn-65 from low chronic levels than from high temporary concentrations of the isotope. The importance of euphausiids in transport and cycling of Zn-65 is discussed with respect to moulting, predation and diel migration.

1583. Fowler, S.W. 1974. The effect of organism size on the content of certain trace metals in marine zooplankton. Rapp. Comm. int. Mer Medit. 22(9):145-146.

Assays with euphausiids and pelagic shrimp showed that concentrations of Zn, Fe, and Mn were inversely correlated with dry body wt. Depending upon crustacean species, concentrations of metals in smaller individuals were 1.2 to 4.1 times greater than larger individuals of the same species. Copper concentration tended to be a direct function of dry weight. Concentrations of Zn, Fe and Mn were generally higher in molts and dissected exoskeletons than muscle tissue; however, the opposite was true for Cu. Material shed by euphausiids in molting ranged from 4.7 to 10.9% of dry body wt with smaller animals tending to lose a greater percentage of body wt than larger specimens. These molts (40-50% ash)contained 15-20, 19-45, 28-40 and 15% of total body Zn, Fe, Co, Mn, respectively. Only 5% of total body Cu content was associated with the molt. In addition, molts from smaller crustaceans had higher concentrations of Zn and Fe than larger species. Results suggest that surface sorption is important in accumulation of Zn, Fe and Mn. Some metals in exoskeleton may serve a metabolic function since certain metalloenzymes are associated with new shell of crustaceans just before molt. However, a relatively large fraction of animal's metal content is associated with outermost layer of exoskeleton which is relatively inactive metabolically. Ecologically, the rapid molting frequency of these crustacea (every 4-10 days), the relatively high concentration of certain metals in the exuviae, and the slow breakdown of the chitinous molt, make the process of molting an important vector in the downward transport of metals in the sea.

The direct relationship between Cu content and body weight in Pasiphaea plus the fact that Cu values were lower in molts than in muscle tissue of other crustaceans indicate that surface area is probably not of major importance in concentration of Cu by planktonic crustaceans. Cu is associated with respiratory pigment haemocyanin, therefore, a greater pigment concentration to facilitate more rapid gas exchange in larger carids might account for the relationship between Cu and body size in Pasiphaea; although presence of haemocyanin in euphausiids is only speculative at this point. Analyses of different size groups of crustaceans show that changes in metal content within one species may be attributable to size alone; therefore, care should be taken to include this factor when establishing baseline levels of metals in aquatic organisms.

1584. Fowler, S.W. and G. Benayoun. 1976. Selenium kinetics in marine zooplankton. Marine Sci. Communications 2:43-67.

Radiotracer studies of bioaccumulation and excretion kinetics of selenium in the euphausiid *Meganyctiphanes norvegica* showed that Se is accumulated both from water and through food chain with highest concentration factors occurring through food. As much as 66% of ingested dose of Se is accumulated into internal tissues. Authors conclude that Se uptake in nature occurs primarily through food chain. Stable Se tissue concentrations were highest in viscera at 11.7 µg Se/g dry wt, followed by eyes, muscle and exoskeleton at 7.81, 1.77 and 0.84 µg Se/g dry wt, respectively. Turnover of Se was rapid; biological half-time of only 37 days was computed for a Se pool which exhibited slowest rate of isotope excretion. Fecal pellet deposition and soluble excretion processes accounted for 54% and 43%, respectively, of total Se excreted. Fecal pellets which contain higher Se concentrations than original food, were assessed as possible biological mechanism for the downward vertical transport of Se.

1585. Fowler, S.W. and G. Benayoun. 1976. Influence of environmental factors on selenium flux in two marine invertebrates. Marine Biology 37:59-68.

Over a Se concentration range 0.1 to 100 µg Se/1, bioaccumulation of Se by mussels *Mytilus galloprovincialis* was strongly dependent on ambient Se concentration in seawater. Mussels accumulated Se^{4+} to a greater extent than Se^{6+}. Increasing temperature from 13 C to 24 C approximately doubled Se concentration factor after 13 days uptake. Mussels were typed according to size, with different concentration factors for each group. For mussels averaging 2.1 g wet wt, the mean C.F. was 46; for 13.2 g wet wt, the C.F. was 29; and for 21.8 g wet wt, it was 13. Presence of varying amounts of Hg significantly altered Se uptake kinetics in mussels. Shrimp *Lysmata seticaudata* accumulated Se to a lesser extent than mussels, with difference in concentration factors attributable to the large amount of sorbed isotope lost with shrimp molts. Once incorporated, Se was lost more rapidly from shrimp than from mussels. Temperature influenced Se loss from mussels but not from shrimp. Neither the chemical form of Se nor Hg concentration affected loss of Se from mussels. More rapid loss of Se was noted from shrimp which had absorbed the isotope directly from water than via food chain.

Biological half-times for Se ranged from 58 to 60 days for shrimp and 63 to 81 days for mussels. In the case of mussels, turnover rates measured in animals maintained in the laboratory differed from those in field. Observed variations in flux rate may have been due to differences in food availability in the two experimental systems.

1586. Fowler, S.W. and G. Benayoun. 1976. Accumulation and distribution of selenium in mussel and shrimp tissues. Bull. Environ. Contamin. Toxicol. 16(3):339-346.

Mussels *Mytilus galloprovincialis* and shrimp *Lysmata seticaudata* collected near the port of Monaco were subdivided into several groups. One group of mussels and shrimp was maintained in seawater containing 0.8 μCi/l Se-75 (>160 μCi/μg Se as sodium selenite). Another group of shrimp were maintained in flowing seawater and fed *ad libitum* on mussels that had previously accumulated Se-75 for several days. The remaining shrimp and mussels were analysed for stable selenium. *Mytilus* readily accumulated Se-75 from the medium and did not appear to have reached a steady state after 63 days; highest Se-75 concentrations were in visceral mass, followed by gills, muscle, and mantle in that order. Shrimp, over a 51-day period, accumulated Se-75 from the water with highest concentrations found in exoskeleton (60-90% of total Se-75 body burden). When Se-75 uptake in shrimp occurred via food chain, the highest activity was in viscera and exoskeleton, suggesting that ingested Se is readily translocated from internal to external tissues. During uptake, molting did not significantly affect Se-75 concentration in exoskeleton, since the percentage of the Se-75 body burden retained in molts was relatively low (about 6%). Concentrations of stable selenium in shrimp, on a mg Se/kg dry wt basis, were as follows: viscera, 7.0; eyes, 4.8; whole shrimp, 2.6; muscle, 1.9; exoskeleton, 1.5; and molts, 0.3. For mussel, these values were: gills, 7.0; whole soft parts, 6.1; mantle 5.2; viscera 3.2; muscle, 1.9; and shell, <0.05 mg Se/kg dry wt. The relative order of stable Se levels in mussels were quite different from that achieved by tissues accumulating Se-75 from the water, indicating that water route may be relatively unimportant in attaining equilibrium for selected tissues. The relative order of stable Se concentrations in shrimp tissues agrees with that observed for Se-75 in tissues after uptake for 51 days via the food chain.

1587. Fowler, S., M. Heyraud and T.M. Beasley. 1975. Experimental studies on plutonium kinetics in marine biota. *In* Impacts of nuclear releases into the aquatic environments. Int. Atom. Ener. Agen., Vienna, Paper SM-198/23:157-177.

Laboratory experiments were conducted to measure plutonium flux through marine organisms and to clarify pathways by which this element is cycled in the marine environment. Use of a specially prepared isotope, plutonium-237 (1/2 life 46 days), allowed measurements to be made with standard NaI(Tl) scintillation techniques. Mussels Mytilus galloprovincialis, shrimp Lysmata seticaudata, and worms Nereis diversicolor accumulated plutonium-237 from seawater for up to 25 days. Accumulation by shrimp was relatively slow with degree of uptake strongly influenced by molting. Cast molts contained large fractions of the shrimps' plutonium content, indicating the high affinity of Pu for surface areas. Only small amounts of the isotope in molt are lost to water; hence, molting is considered to be an important biological parameter in biogeochemical cycling of plutonium. Mussels attained higher concentration factors than shrimp with most of the accumulated isotope (>80%) located in shell. Byssus threads often contained large fractions of the mussels' plutonium-237 content and reached C.F. up to 4100. Worms readily accumulated plutonium-237 in either the +4 or +6 state, reach- C.F. of approximately 200. Retention studies indicated a relatively slow loss of plutonium-237 from all animals studied. With mussel, a computed half-time for most of the animals' plutonium content was about 2 years. The more rapid loss from shrimp ($Tb_{1/2}$ = 1.5 months) was due principally to the large fraction of plutonium lost at molt. Food chain studies with shrimp indicated that tissue build-up via plutonium ingestion would be a slow process. Total excretion was not entirely a result of passing contaminated food through the gut; approximately 15% of the ingested plutonium was removed from the contaminated food and subsequently excreted by processes other than defecation of labelled food. Ratios of four different plutonium isotopes used in the experiments showed that when isotopes were present together in the same physicochemical form, no differences in isotopic behavior were evident—even when total mass of certain isotopes in the system differed by 10^3. Authors concluded that plutonium-237, because of its relatively high specific activity, offered the best possible means for tracing plutonium biokinetics in aquatic systems in which the experimental design dictates that total plutonium concentrations approximate those currently found in the environment.

1588. Fowler, S.W., J. LaRosa, M. Heyraud, and W.C. Renfro. 1975. Effect of different radiotracer labelling techniques on radionuclide excretion from marine organisms. Marine Biology 30: 297-304.

Amphipods Gammarus locusta, which accumulated Zn-65 under a close approximation of natural conditions excreted the radiotracer during a 3-month period at a markedly different rate than amphipods labelled with Zn-65 in the laboratory via different combinations of radioactive food and seawater. Shrimp Lysmata seticauda, administered Zn-65 by 3 different methods in the laboratory displayed different excretion kinetics during the first 2 months of loss. Differences among excretion rates most likely were a reflection of degree to which various zinc pools within shrimp had equilibrated with Zn-65. During the next several months all Zn-65 loss rates were quite similar, probably indicating that radiotracer excretion was taking place from similar zinc pools within shrimp. Importance of adequate radiotracer labelling techniques, as well as proper design of subsequent excretion experiments in studies on flux rates of the corresponding stable metal is discussed. Authors concluded that laboratory radiotracer experiments which are intended to supply information on actual situations in the sea require careful design and execution.

1589. Fowler, S.W. and B. Oregioni. 1976. Trace metals in mussels from the N.W. Mediterranean. Marine Poll. Bull. 7:26-29.

Mean content of selected metals, in mg/kg dry wt, of Mytilus galloprovincialis soft parts from 15 sites in the NW Mediterranean Sea were: 0.76 for Ag, 1.9 for Cd, 2.8 for Co, 7.5 for Cr, 18.0 for Cu, 443 for Fe, 21 for Mn, 4.3 for Ni, 21 for Pb, and 209 for Zn. Highest values for most metals were in samples from port cities and areas near river discharges. Seasonal variations were evident, with an overall increased concentration in March 1974 attributed to high precipitation and runoff. Data comparison indicates that average metal levels in NW Mediterranean mussels do not differ markedly from those of similar species throughout the world.

1590. Fowler, S.W., L.F. Small and J. LaRosa. 1972. The role of euphausiid molts in the transport of radionuclides in the sea. Rapp. Comm. Int. Mer Medit. 21(6):291-292.

Meganyctiphanes norvegica in a mixed-isotope seawater medium for 5 days, shed molts containing 53, 39, 59 and 75% radioactive Co, Mn, Zn, and Fe, respectively. Percentages were reduced to 3.5, 2.4, 3.3 and 10.6% when isotopes were accumulated by grazing on radioactive Artemia. Radioisotope content of molts decreased sharply in subsequent molts. Molts which disintegrated in 48 to 96 hrs lost incorporated isotopes at an exponential rate. Decreasing loss rate order was Mn-54, Zn-65, Co-57 and Fe-59. Authors concluded that euphausiid molts constituted important vehicles of radioisotope transfer into marine ecosystems.

1591. Frazier, J.M. 1975. The dynamics of metals in the American oyster, Crassostrea virginica. I. Seasonal effects. Chesapeake Science 16:162-171.

Seasonal dynamics of Mn, Fe, Zn, Cu, and Cd were investigated in a genetically similar population of hatchery-reared oysters. Concentrations in whole soft tissues, in mg/kg, for Mn ranged from 30 (Oct) to 2 (Dec); Fe ranged from 510 (Oct) to 150 (Dec); Zn from 5,000 (Aug) to 2,100 (Nov); Cu from 250 (Aug) to 50 (Oct); and Cd from 16 (Aug) to 3 (Oct). Average shell concentrations (in mg/kg dry wt) were Mn 505, Fe 19, Zn 2.5, Cu 0.16, and Cd <0.1. Bottom sediments had average concentrations (in mg/kg dry) of 18,200 for Fe, 57 for Mn, 46 for Zn, 32 for Cr, 11 for Pb, 6 for Cu, 6 for Ni, 2.7 for Co, and 0.3 for Cd.

Metals were grouped into two classes according to their dynamics: (1) Mn and Fe concentrations in soft tissues were significantly correlated with shell deposition. A high rate of Mn turnover in soft tissues (∿2X the body burden/day) occurred during shell growth seasons, (2) Zn and Cu concentrations were not correlated with shell growth. Zn and Cu body burdens exhibited a gradual increase during spring and early summer followed by a rapid loss during August-September in which 33% of Zn and 50% of Cu was lost in <4 weeks. Cd behavior was similar to Zn and Cu with a 50% reduction in body burden during an 11 week period between July and October.

1592. Frazier, J.M. 1976. The dynamics of metals in the American oyster, Crassostrea virginica. II. Environmental effects. Chesapeake Science 17:188-197.

Hatchery-reared oysters were exposed in situ to metal-contaminated sediments (experimental) and non-contaminated (control) environments from September 1972 to August 1973. The amount of contamination was reflected in levels of Mn, Fe, Zn, Cu, and Cd in sediment samples. For experimentals this was (mg/kg dry wt) 90 Mn, 26,300 Fe, 232 Zn, 123 Cu, 0.7 Cd; for controls 50 Mn, 18,800 Fe, 48 Zn, 5.6 Cu, and 0.3 Cd. On a dry wt basis Zn and Cu were accumulated in soft tissues of experimental oysters to levels of 4,100 mg Zn/kg and 450 mg Cu/kg; for controls these were 1,700 mg Zn/kg and 60 mg Cu/kg. Relative accumulations of metals in soft tissues of experimentals when compared to controls reflected relative metal concentrations between the two environments. Growth of oysters, measured by soft tissue dry weight and shell dimension was identical for the two groups but shells of experimentals were 16% thinner than controls. Trace metal incorporation into shell was affected with Mn incorporation surpressed and Fe, Zn and Cu slightly increased. Uptake of metals by oyster soft tissues was seasonally dependent with rapid uptake occurring in summer and fall but delayed uptake in the early spring.

1593. Freeman, H.C. and D.A. Horne. 1973. The total mercury and methylmercury content of the American eel (Anguilla rostrata). Jour. Fish. Res. Bd. Canada 30:454-456.

Total Hg content of Nova Scotian eels was 0.72 ± 0.05 mg/kg wet wt; methylmercury content was 0.40 ± 0.06 mg/kg wet wt. Since the mean total Hg content was less than 1 mg/kg wet wt and the toxic methylmercury content was 50% of this, or less than the 0.5 mg/kg wet wt guideline, such eels were considered acceptable for human consumption.

1594. Freeman, L. and I. Fowler. 1953. Toxicity of combinations of certain inorganic compounds to *Daphnia magna*. Sewage Indust. Waste. 25(10):1191-1195.

The concentration of sodium chromate which immobilized 50% of treated microcrustaceans, *D. magna*, decreased from 0.42 mg/l when applied alone, to 0.276 mg/l in combination with 2984 mg sodium sulfate/l, and to 0.159 mg/l when combined with 93 mg sodium silicate/l. Further reductions occurred when additional inorganic Na salts were added.

1595. Fretter, V. 1953. Experiments with radioactive strontium (^{90}Sr) on certain molluscs and polychaetes. Jour. Mar. Biol. Assn. U.K. 32:367-384.

In *Arion hortensis*, a land pulmonate, dietary Sr-90 was taken up by digestive cells, haemocoel, and digestive gland lime cells, where it eventually concentrated around Ca spherules. Some Sr-90 entered the body through the intestinal wall. Ca stores surrounding the blood vessels and mantle Ca cells also concentrated Sr-90. In marine molluscs *Aplysia punctata* and *Acanthodous pilosa* Sr-90 from surrounding water passed through body surfaces and gills. In *A. pilosa*, ions which enter tissues from seawater accumulated around Ca concretions in mantle. Both marine species obtained cations directly from water as well as food. *Mytilus edulis* localized Sr-90 for excretion within 10 hrs; ions were aggregated in pericardial glands. When mussels were kept in a medium with elevated Sr content, amoebocytes containing Sr-90 and its decay product yttrium were found in connective tissue of labial palps and in gill blood spaces. Amoebocytes of *Calyptraea chinensis* accumulated Sr-90 from filtered seawater; lymphoidocytes of *Platynereis dumerili*, a polychaete, concentrated Sr-90 and transported it to outer body surface.

1596. Fujiki, M. 1963. Studies on the course that the causative agent of Minamata Disease was formed, especially on the accumulation of the mercury compound in the fish and shellfish of Minamata Bay. Jour. Kumamoto Med. Soc. 37(9):494-521. (In Japanese)

A series of studies were initiated to measure mercury content in fish and shellfish from Minamata Bay, to determine accumulation by shellfish under laboratory conditions, and to establish mercury transfer from shellfish to rats in feeding studies.

Mercury content in whole clam Hormomya mutabilis from Minamata Bay ranged up to 85 mg/kg dry wt; most active sites were ganglion (181 mg/kg), gill (87 mg/kg) and digestive gland (73 mg/kg). Edible muscle from 5 species of fishes collected from Minamata Bay contained, in mg/kg dry wt, 0.9, 14, 16, 58, and 309, respectively. Uptake studies with clam Venus japonica held in seawater media containing 0.3 mg/l of Hg^{2+}, and 0.3 mg/l of other compounds including arsenic or selenium indicated that after 7 to 12 days survivors contained 39 to 148 mg Hg/kg whole body; most clams died during exposure. Uptake was higher and death rate greater when methylmercury compounds were tested. Some accumulation of Hg was observed in kidney and liver of rats fed Venus cultured in seawater containing mercury compounds. However, mercury content was substantially higher in rat liver (up to 440 mg/kg dry wt), kidney (383 mg/kg) and brain (86 mg/kg) when fractions of the mercury sludge from the acetaldehyde plant were administered.

1597. Fujita, M. and K. Hashizume. 1975. Status of uptake of mercury by the freshwater diatom, Synedra ulna. Water Research 9:889-894.

Preliminary studies of 8 days duration established a lethal concentration of mercuric chloride between 10 and 50 ug/l. Using Hg-203 labelled mercuric chloride, Synedra took up mercury rapidly from surrounding water. Cells attained maximum uptake during the first 7 h. Comparison of mercury uptake by dividing cells with that of non-dividing, heat killed cells and their silicate shells showed that factors other than cell-division or photosynthesis were responsible for mercury uptake by Synedra. About 20% of the total amount of mercury found in dividing cells was taken up by passive adsorption; about 50% was accumulated in the inner part of cells. Synedra took up 0.45 um filterable or ionic mercury rather than particulate mercury larger than 0.45 um.

1598. Fujita, M., E. Takabatake and K. Iwasaki. 1976. Effects of light, magnesium and cyanide on accumulation of mercury by a freshwater diatom, Synedra. Bull. Environ. Contamin. Toxicol. 16:164-172.

Uptake of mercury by Synedra was much higher under illumination than in darkness. Increasing concentrations of magnesium were associated with increasing Hg uptake by Synedra until an optimal concentration of 0.1 mM is reached. At higher concentrations of Mg^{2+}, Hg uptake is drastically reduced. These increases suggest the presence of an active uptake linked to energy metabolism which requires light and Mg^{2+}. Cyanide and azide, potent inhibitors of respiratory enzymes, effectively prevented Hg uptake. In presence of 0.01 mM CN^-, uptake was reduced to 50% of controls. Azide also inhibited uptake but less effectively.

Mercury accumulation observed in dark or by dead cells was attributed to passive adsorption.

1599. Fujita, T. 1971. Concentration of major chemical elements in marine plankton. Geochem. Jour. 4:143-156.

Plankton samples collected in coastal and off-shore areas near Japan were sorted and analyzed for Na, K, Ca, Mg and Si. Mean values for zooplankton samples of single species, which included crustaceans, tunicates, protozoa, coelenterates and chaetognaths, in mg/g dry wt were: Na 4.0, K 5.0, Ca 3.9, Mg 3.8 and Si 4.3. Mean values for mixed zooplankton in mg/g dry wt were: Na 2.8, K. 9.8, Ca 8.7, Mg 4.8, and Si 27. Mean values for samples of mixed phytoplankton species in mg/g dry wt were: Na 1.4, K. 68.7, Ca 6.4, Mg 5.9, and Si 195.

1600. Fujita, T. 1972. The zinc content in marine plankton. Records Oceanog. Works Japan 11(2):73-79.

Zinc content in 48 samples of zooplankton representing crustaceans, coelenterates, tunicates, and chaetognaths of single species and 18 samples of phytoplankton of mixed species ranged from 20 to 1,069 mg/kg dry wt in zooplankton, and 104 to 1,757 mg/kg dry wt (average 590 mg/kg) in phytoplankton.

1601. Fujita, T., T. Yamamoto, I. Yamazi and T. Shigematsu. 1969. The contents of ash, iron and manganese in marine plankton. Jour. Chem. Soc. Japan 90:680-686. (In Japanese)

Iron and manganese values in plankton species collected between 34°59' north latitude - 136°41' and 34°57' - 136°47' are shown for crustaceans, chaetognaths, annelids, molluscs, algae and tunicates. Iron values in g/kg wet wt ranged from 0.1 for euphasiids to 5.2 for *Acartia clausi*, a copepod; for Mn, these were 0.002 g/kg wet wt (euphasiids) to 0.188 for *Acartia clausi*. Fe/Mn ratios ranged from a low of 5.6 for salps to 93.2 for euphasiids.

1602. Fukai, R. 1965. Analysis of trace amounts of chromium in marine organisms by the isotope dilution of Cr-51. *In* Radiochemical methods of analysis, Int. Atom. Energy Agency, Vienna: 335-351.

Chromium concentrations, in mg/kg dry wt, of various marine organisms from the Mediterranean Sea were 1.55 for algae *Entermorpha linza*; 1.42 for algae *Cystoseira myriophylloides*; 1.52 for copepod *Acartia clausi*; 0.11 for soft parts of shrimp *Parapenaeus longirostris*;

0.48 for meat of crab *Eriphia verrucosa*; 0.97 for soft parts of mussel *Mytilus edulis*; 1.29 for soft parts of gastropod *Murex trunculus*; 0.28 for muscle of sea cucumber *Holothuria forskalii*; 0.14 for muscle of sardine *Sardina pilchardus*; and 0.22 for muscle of bogue (teleost) *Boops boops*.

1603. Fukai, R. and D. Broquet. 1965. Distribution of chromium in marine organisms. Bull. Inst. Oceanogr. 65(1336):1-19.

Chromium content for various species of seaweeds ranged from 0.4 to 2.5 mg Cr/kg dry wt, with 60% of the values in the range of 0.6 to 1.5. Values for *Zostera* were higher at 1.3 to 4.2 mg Cr/kg dry wt. Variations in Cr content of seaweeds were apparently unrelated to species, seasons, or collection locales. Chromium in seaweeds may be the result of surface contamination through silt or other particles. Cr content in mg Cr/kg dry wt was high in polychaetes at 8.1 to 14.7; for crustaceans Cr ranged from 0.09 in king crab meat *Paralithodes kamtschatica*, to 2.1 for whole copepods *Clausocalanus* and *Paracalanus*. Cr content in soft parts of bivalves and gastropods ranged from 0.5 to 1.6 mg Cr/kg dry wt; for cephalopods this was 0.07 to 0.12. The lower Cr content of cephalopods may be due to their pelagic rather than benthic mode. Cr content in echinoderms ranged from 0.3 to 1.2 mg Cr/kg dry wt; and for fish it was 0.03 to 0.5. Iron content of samples was also determined in order to compare the Fe/Cr ratio with that of marine sediments, since Cr^{+3} in seawater is coprecipitated with iron hydroxide.

1604. Fukai, R. and W.W. Meinke. 1959. Some activation analyses of six trace elements in marine biological ashes. Nature 184: 815-816.

Metal levels, in mg/kg ash, for the seaweed *Ulva* were 5.9 to 13.3 for vanadium, 0.13 to 0.18 for tungsten, 0.046 to 0.073 for rhenium, 0.015 to 0.093 for gold and 5.4 for arsenic. *Porphyra*, an alga, contained 262 and 17 mg/kg ash of V and molybdenum, respectively. Clams *Tapes japonica*, and prawns *Pandalus* sp, contained respective levels, in mg/kg ash wt, of 15 and 1.1 for V, <0.05 and 0.83 for As, 0.46 and <0.005 for W, 0.064 and <0.005 for Re, and 0.079 and 0.0046 for Au. Mackerel *Pneumatophorus japonicus* flesh had, in mg/kg ash wt, 0.34 for As, <0.014 for W, <0.008 for Re, and 0.0026 for Au.

1605. Fukai, R. and W.W. Meinke. 1962. Activation analyses of vanadium, arsenic, molybdenum, tungsten, rhenium, and gold in marine organisms. Limnol. Oceanogr. 7:186-200.

Metal levels, in mg/kg dry wt, of alga *Ulva* sp. and *Porphyra* sp., were 1.3 to 3.1 for vanadium, 1.2 for arsenic, n.d. to 1.0 for molybdenum, 0.029 to 0.042 for tungsten, 0.011 to 0.016 for rhenium, and 0.021 to 0.0035 for gold. Respective values, in mg/kg dry wt, for soft parts of clam *Tapes japonica*, soft parts of prawn *Pandalus* sp., and muscle of mackerel *Pneumatophorus japonicus*, were: 1.1, 0.07, and n.d. for V; <0.004, 0.05 and 0.015 for As; 0.03, <0.0003 and <0.0006 for W; 0.0046, <0.0003 and <0.0004 for Re; and 0.0057, 0.00028 and 0.00012 for Au.

1606. Furukawa, K. and K. Tonomura. 1972. Induction of metallic mercury-releasing enzyme in mercury-resistant *Pseudomonas*. Agr. Biol. Chem. 36(13):2441-2448.

Formation of metallic mercury-releasing enzyme (MMR-Enz) which catalyzes reduction of mercurials to metallic Hg was induced when the organism was grown with mercurials such as phenylmercuric acetate (PMA), p-chloromercury benzoate (pCMB), sodium ethyl mercuric thiosalicylate (merzonin), mercuric chloride (MC) and metallic mercury. It was not induced when grown with HgS or other metals such as Ag, Cd, Cu, Fe, Co, or Sn. Cadmium and Cu inhibited MMR-Enz formation. D-glucose:NAD oxidoreductase or L-arabinose:NADP oxidoreductase and cytochrome c-I which were all involved in decomposition of mercurials together with MMR-Enz were present in the crude extract regardless of mercurial addition. Authors suggest that MMR-Enz plays a conclusive role in decomposition reaction of mercurials.

1607. Gajan, R.J. and D. Larry. 1972. Metals and other elements. Determination of lead in fish by atomic absorption spectrophotometry and by polarography. I. Development of the methods. Jour. Assoc. Off. Anal. Chemists 55:727-732.

A method for determination of Pb in 12 species of freshwater and marine fish species by atomic absorption spectrophotometry and polarography is described with good agreement between the two at levels of 1.0 to 10.0 mg/kg. Over this range, recoveries averaged 96.1% for polarography and 93.8% for A.A.S. Determinations of Pb levels in fish using both methods were, in mg/kg ash wt, between 0.1 and 0.4 for salmon, 0.2 and 0.8 in sucker, 0.1 and 0.9 in coho salmon, 0.1 and 0.8 in sheephead, 0.2 and 0.8 in carp, 0.2 and 0.8 in catfish and between 0.1 and 1.3 in perch.

1608. Galtsoff, P.S. 1942. Accumulation of manganese and the sexual cycle in *Ostrea virginica*. Physiol. Zool. 15:210-215.

Manganese levels, in mg/kg dry wt, of oysters collected throughout the year, were 51 to 59 for ripe ovaries, 4 to 7 for ripe testes, 17 (winter) to 38 (summer) for gill, 8 (winter) to 17 (late summer) for mantle, and 3 to 9 for adductor muscle, yielding whole body concentrations of 7 to 11 in winter and 28 to 57 in summer. Peak Mn concentrations coincided with maximum gonad development and sexual activity, apparently, in response to accumulation in ovaries. Gills in both sexes showed similar seasonal trends.

1609. Galtsoff, P.S. 1953. Accumulation of manganese, iron, copper, and zinc in the body of American oyster, Crassortaea (Ostrea) virginica. Anatom. Rec. 117:601-602. (Abstract)

Oysters contained metal levels in mg/kg dry tissue, of 9 to 60 for Mn, 140 to 800 for Fe, 670 to 3000 for Cu and 500 to 13,700 for Zn; concentrations were highest from June to October. Mn and Fe levels were more stable than Cu and Zn. Cu, Fe and Zn were stored in gill and mantle; Mn was concentrated during reproduction in ovaries, but not in testes. Fe and Cu concentrations in oysters were increased by addition of salts of these metals to water in which mollusks were kept. Iron oxide was adsorbed primarily by phagocytes present on gill surface, even during winter suppression of feeding. During feeding season, Fe was absorbed through digestive tract, although greatest portion of metal delivered to intestines was discharged with feces. Excretion was by diapedesis and through mantle mucous cells.

1610. Galtsoff, P.S. and D.V. Whipple. 1930. Oxygen consumption of normal and green oysters. U.S. Dept. Commerce, Bull. Bur. Fisheries 46:489-508.

Green pigment of oysters is not a hemocyanin or copper proteinate of any kind; the compound exists in a highly dissociated state. Copper content of normal oysters varies between 8.21 to 13.77 mg/100 grams dry wt, or from 0.16 to 0.248 mg per oyster. Copper content of green oysters analyzed during the investigation varied between 121 and 271 mg per 100 grams dry wt, or from 1.24 to 5.12 mg per oyster. Green oysters show a slight increase in oxygen consumption over normal oysters; the significance of this difference is, however, doubtful.

1611. Ganther, H.E., C. Goudie, M.L. Sunde, M.J. Kopecky, P. Wagner, S.-H. Oh, and W.G. Hoekstra. 1972. Selenium: relation to decreased toxicity of methylmercury added to diets containing tuna. Science 175:1122-1124.

Samples of canned tuna muscle show average levels of 1.91 to 2.91 mg Se/kg wet wt and 0.32 to 2.87 mg Hg/kg. Se and Hg in tuna appear to be accumulated in a relatively constant ratio. Japanese quail, *Corturnix corturnix japonica*, given 20 mg methyl-Hg/kg in diets containing 17% (by wt) tuna survived longer than quail given this concentration of methyl-Hg in a corn-soya diet. Methyl-Hg toxicity in rats was decreased by dietary Se supplement comparable to that supplied by tuna. Authors concluded that selenium in tuna, far from being a hazard in itself, may lessen the danger to man of mercury in tuna.

1612. Garder, K. and O. Skulberg. 1966. An experimental investigation on the accumulation of radioisotopes by freshwater biota. Arch. Hydrobiol. 62(1):50-69.

Representative species of algae, higher plants, fishes and invertebrates were exposed for 5 months in river water to radioisotopes of selected metals. Exposure levels in μCiX10^{-6}/1, were 1.2 for Zr-95-Nb-95, 2.1 for Cs-137, 6.0 for Ce-144, 7.8 for Sr-89 and 7.8 for Ru-103. Mean post-exposure values in μCi/kg wet wt in algae *Vaucheria walzii* were 2.1 for Zr-Nb, 1.0 for Cs, 7.2 for Ce, 2.9 for Sr and 132 for Ru. For *Eurycercus lamellatus*, a cladoceran, and *Anodonta piscinalis*, a lamellibranch, these were 0.8 and 0.8 for Cs-137, 4.8 and 0.4 for Sr-89, 2.3 and 0.8 for Ce-144, and 0.7 and 0.2 for Zr-95-Nb-95. After 9 days exposure to Cs-137 at levels of 10^{-2} μCi/1, Cs-137 levels in the vascular plants *Alisma plantagoaquatica* and *Elatine triandra* were 0.05 and 0.12 μCi/kg wet wt, respectively. Brown trout *Salmo trutta*, and minnows *Phoxinus phoxinus*, accumulated Cs-137 up to 10X media concentrations.

1613. Gardner, G.R. 1975. Chemically induced lesions in estuarine or marine teleosts. *In* Ribelin, W.E. and G. Migaki (eds). The pathology of fishes. Univ. of Wisconsin Press, Madison, Wisc.: 657-693.

Damage to sensory organ systems of teleosts was demonstrated by salts of Cu, Hg, Ag, Cd, and Zn and also methoxychlor, crude oil, and pulp mill effluents. Initial studies with chloride salts of silver at 5 mg/1, cadmium at 65 mg/1, copper at 15 mg/1, mercury at 1 mg/1, and zinc at 70 mg/1 were conducted to measure effects on gills after 48 hrs exposure. Concentrations of these five metals, considered to be acutely toxic to mummichog *Fundulus heteroclitus*, elicited a heavy gill-mucus response. Heavy mucus concentrations did not occur uniformly across any one gill arch, or cause complete collapse of respiratory structure. Accumulations were lower in animals exposed to Cd and Hg than Ag, Cu, and Zn. Apical areas of many gill filaments were necrotic following exposures to Cd and Hg, with cartilaginous filament rods being denuded and exposed. Mercury, Ag, and Cu were neurotoxic with lesions observed in olefactory and lateral line systems; damage syndromes were not similar. Cadmium and Zn exposures did not cause morphological anomolies of neurosensory structures of mummichog.

Mercury levels of 0.5 mg/l or higher caused severe cytoplasmic and nuclear degeneration of all cellular elements of the lateral line canals in mummichog. The necrocytosis affected secretory cells of canal lining, squamous epithelium of canal walls, and canal's secretory and mucus cells. Neurosensory hillocks within these canals usually were necrotic. Severe degenerative changes in mummichog olfactory organs also accompanied Hg concentrations of 0.5 mg/l and higher. Various degrees of cellular degeneration were identifiable in neurosensory cells of these organs. However, no evidence of hyperplasia or widespread necrosis, such as that observed following copper exposures, could be associated with the sustentacular cells. The degree of morphological alteration to neurosensory cells was generally uniform throughout the organ, except basally where the lesion had progressed further.

Silver, like Hg and Cu, exerted a toxic effect within canals of the cephalic lateral line extension of mummichog. The change was most similar to those following Cu exposures. Epithelial lining of olfactory pit and sustentacular epithelium of olfactory organs were affected, as indicated by widespread cellular degeneration. Sensory organs were usually apically necrotic in these cases. Although all fish exposed to Ag did not exhibit these changes, at least one did at every Ag concentration studied. In spite of the small number of animals tested, the occurrence of the lesion in lateral line and olfactory organs seemed to be an "all or none" reaction. The condition was always severe if present, regardless of toxicant concentration.

No identifiable lesions were associated with intestine, kidney, or circulating blood cells of mummichog exposed to 5 mg/l of Cd at any time during test of one year duration; these tissues in mummichog are known to be altered by higher levels of Cd. However, subtle alterations were observed in thyroid. The thyroid of several animals was hyperplastic following 3 months of continuous exposure, as evidenced by a marked increase in number of follicles. This condition was evident through the eighth month of continuous exposure, but not as pronounced afterwards. Approximately 10% of the specimens examined in the third and eighth months had the thyroid condition; the proportion rose to nearly 80% during the seventh month (September). Because of the early loss of control organisms, it was not possible to link hyperplasia with Cd.

1614. Gardner, W.S., H.L. Windom, J.A. Stephens, F.E. Taylor and R.R. Stickney. 1975. Concentrations of total mercury in fish and other coastal organisms: implications to mercury cycling. In Howell, F.G., J.B. Gentry, M.H. Smith (eds.). Mineral Cycling in Southeastern Ecosystems. U.S. Energy Res. Dev. Admin.: 268-278. Available as CONF-740513 from NTIS, U.S. Dept. Comm. Springfield, VA 22161.

Total and methyl Hg concentrations were determined for a variety of aquatic organisms from several estuaries of the southeastern

U.S. Roots of Spartina, a prominent marsh plant, had higher concentrations of Hg than stems or leaves (0.78 vs. 0.23 mg/kg dry wt) with no methylmercury detected. Hg levels in muscle of 20 fish species generally ranged between 0.1 and 1 mg/kg dry wt with exceptional values of 1.8 and 2.9 in sea catfish Arius felis, and toadfish Opsanus tau, respectively. Average Hg muscle concentrations in 8 species of elasmobranchs ranged from 1.5 to 4 mg/kg dry wt. Methylmercury accounted for 70% of total mercury in muscle of fish and elasmobranchs. Relative quantity of methylated Hg in livers of fish and elasmobranchs ranged from 3% for Carcharhinus milberti (sand bar shark) to 48% of total Hg for flounder. Of crustaceans examined, blue crab muscle contained 0.45 mg Hg/kg dry wt of which 68% was methylated. Average Hg muscle concentration of 4 species of shrimp was 0.22 mg/kg dry wt of which 43% was methylated.

Preliminary studies have shown that methyl mercury potentially can be transported upward through Spartina plants. If the mercury is released to water column, it could be taken up by fish, and this could account for the higher mercury levels in finfish than intermediate food-chain members.

1615. Gebhards, S., F. Shields and S. O'Neal. 1971. Mercury levels in Idaho fishes and aquatic environments, 1970-71. State of Idaho Fish & Game Dept. and Dept. of Health. 23 pp.

Maximum mercury concentration found in 1,096 fish representing 26 species was 1.7 mg/kg wet wt in a squawfish. Piscivores exhibited higher Hg levels than plankton or insect feeders. Warmwater non-game fish species contained 2X the Hg levels found in coldwater (trout and whitefish) game fish. Mercury levels in fish from reservoirs were higher than those from contributing streams. Fifty-nine fish or 5.3% of the total contained >0.5 mg Hg/kg wet wt.

1616. George, S.G., B.J.S. Pirie and T.L. Coombs. 1976. The kinetics of accumulation and excretion of ferric hydroxide in Mytilus edulis (L.) and its distribution in the tissues. Jour. Exp. Mar. Biol. Ecol. 23:71-84.

Using Fe-59-labelled ferric hydroxide it was found that Fe-59 accumulates in linear proportion to seawater concentration and is found in all tissues: concentration factors for viscera, kidneys, gills, muscle-mantle is 25:6:4:1, respectively. Particulate iron is taken up by pinocytosis by special epithelial cells in gills, gut, kidney and possibly labial palps and held in membrane-bound vesicles, unaccompanied by mucus in gills and kidney, but with mucus present in the digestive diverticulum and mid-gut cells. There is no free iron within the cytoplasm. Approximately 30% of iron presented to gut is not absorbed, being voided with feces. Absorbed iron is exocytosed and then passed on to amoebocytes in haemolymph for transport to other tissues, a major fraction being excreted by transfer to byssal threads.

1617. Getsova, A.B. and G.A. Volkova. 1962. The accumulation of radioactive isotopes by certain aquatic insects. Entomol. Rev. 41:61-70.

The concentration, accumulation factor, and rate of desorption of Ca-45, Cr-51, Fe-59, Co-60, Zn-65, Sr-90, Zr-35, Ru-106, Cd-115, Cs-137, Ce-144, and Hg-203, were determined at different developmental stages of mosquitoes Culex pipiens pipiens, Theobaldia alaskaensis; caddisflies Halesus interpunctatus, Phryganea grandis, Leptocerus sp.; and dragonflies of the genera Aeschna and Lestes. Accumulation of radioisotopes was different in different species for the same element and for different elements in the same species. In all species the larval stages accumulated more than the pupal stage. Accumulation of radioactive elements is a function of time, with concentrations and accumulation factors increasing with time in some but reaching a plateau in others. Increasing the temperature of the medium increases metabolic rate of insects and facilitates accumulation. The addition of EDTA complexone to water increased desorption of Ru, Ce, Cs, and Sr in caddisfly larvae.

1618. Ghidalia, W., J.M. Fine and M. Marneux. 1972. On the presence of an iron-binding protein in the serum of a decapod crustacean [Macropipus puber (Linne)]. Comp. Biochem. Physiol. 41B:349-354.

Two protein fractions in serum of male M. puber were able to chelate free Fe. One was a Cu protein, perhaps hemocyanin. The second, devoid of Cu, had the same electrophoretic mobility on paper as human transferrin and seemed to be a metal-binding protein.

1619. Ghiorse, W.C. and H.L. Ehrlich. 1976. Electron transport components of the MnO_2 reductase system and the location of the terminal reductase in a marine Bacillus. Appl. Environ. Microbiol. 31(6):977-985.

MnO_2 reduction with glucose by uninduced whole cells and cell extracts of a marine bacterium, Bacillus 29, was strongly inhibited by 0.1 mM dicumarol, 100 mM azide, and 8 mM cyanide but not by atebrine or carbon monoxide, suggesting involvement of a vitamin K-type quinone and a metalloenzyme in electron transport chain. MnO_2 reduction with ferrocyanide by uninduced cell extracts was inhibited by 5 mM cyanide and 100 mM azide but not by atebrine, dicumarol, or carbon monoxide, suggesting that the metalloenzyme was associated with terminal oxidase activity. MnO_2 reduction with glucose by induced whole cells and cell extracts was inhibited by 1 mM atebrine, 0.1 mM dicumarol, and 10 mM cyanide but not by antimycin A, 2n-nonyl-4-hydroxyquinoline-N-oxide (NOQNO), 4,4,4-trifluoro-1-(2thienyl), 1,3-butanedione, or carbon monoxide. Induced cell extract was also inhibited by 100 mM azide, but stimulated by 1 mM and 10 mM azide. Induced whole cells were stimulated by 10 mM and 100 mM azide. Results suggested that electron transport from glucose to MnO_2 in induced cells involved such components as flavoprotein, a vitamin K-type quinone, and a metalloenzyme. Stimulatory effect of azide on induced cells was explained on the basis of a branching in terminal part of electron transport chain, one branch involving a metalloenzyme for MnO_2 reduction, and other involving a metalloenzyme for oxygen reduction. Spectral studies showed presence of a-, b-, and c-type cytochromes in membrane but not in soluble fractions. Of these cytochromes, only c type may be involved in electron transport on MnO_2, owing to lack of inhibition by antimycin A or NOQNO. Terminal MnO_2 reductase appears to be loosely attached to cell membrane of *Bacillus* 29 because on cell fractionation it is found associated with both particulate and soluble fractions. Electron photomicrographs of bacilli attached to synthetic Fe-Mn oxide revealed an intimate contact of cell walls with oxide particles.

1620. Ghiretti-Magaldi, A., A. Giuditta and F. Ghiretti. 1958. Pathways of terminal respiration in marine invertebrates. I. The respiratory system in cephalopods. Jour. Cell. Comp. Physiol. 52:389-429.

Octopus *Octopus vulgaris*, contained iron and copper levels, in mg/kg dry wt, of 1920 and 2550 for hepatopancreas, 399 and 93 for branchial heart, 188 and 111 for gill, 160 and 43 for central heart, 112 and 48 for kidney, 47 and 28 for body muscle, and 0 and 2450 for hemolymph. Further experiments indicate that terminal respiration is catalysed by Fe but not Cu enzymes.

1621. Giblin, F.J. and E.J. Massaro. 1975. The erythrocyte transport and transfer of methylmercury to tissues of the rainbow trout (*Salmo gairdneri*). Toxicology 5:243-254.

In vitro studies showed that approximately 3 min after addition of 5 mg/l Hg as MeHgCl to whole blood, 84% of the Hg was retained in washed trout red blood cells (RBC). Uptake reached 89% after 1 hr and remained constant. *In vivo*, 95% of whole blood Hg was contained in the soluble contents of the RBC's 2 weeks after an intragastric dose of MeHg-203Cl at 4 mg Hg/kg body wt. The binding of MeHg was freely reversible in both. Hemoglobin appeared to be the main MeHg transport protein in trout blood since it bound 90% of whole blood Hg following intragastric dose. MeHg, injected intracardially as MeHgS-cysteine was present in blood and bound almost completely to hemoglobin by 10 days post-injection, suggesting an ability of hemoglobin to compete for and bind MeHg bound to other sulfhydryl (SH) compounds. The number of reactive-SH groups per molecule of trout Hb was determined to be 4. The concentration of Hb reactive -SH groups in trout RBC was calculated to be at least 20 mM which accounts for the high affinity of RBC for MeHg.

1622. Gibson, C.I., T.O. Thatcher and C.W. Apts. 1976. Some effects of temperature, chlorine, and copper on the survival and growth of the coon stripe shrimp. *In* Esch, G.W. and R.W. McFarlane (eds.). Thermal Ecology II. U.S. Energy Res. Dev. Admin.: 88-92. Available as CONF-750425 from NTIS, U.S. Dept. Comm., Springfield, VA 22161.

Toxicity bioassays were conducted with the marine shrimp *Pandalus danae*, acclimated at 8 C and exposed to $CuSO_4 \cdot 5H_2O$ at 10, 15, and 20 C. Mean LC-50 (96-hr) values, in mg Cu/1, were 0.051 at 10 C, 0.035 at 15 C and 0.037 at 20 C. Net growth of shrimp, of initial size 1-2 g, exposed to various copper concentrations for one month at 16 C was also determined: average wt gain, in g, was 0.04 at 0.041 mg Cu/1, 0.12 at 0.009 mg Cu/1, 0.14 at 0.005 mg Cu/1 and 0.09 at 0.002 mg Cu/1. Similar data were collected for selected thermo-chlorine regimens.

1623. Gilfillan, E. 1972. Reactions of *Euphausia pacifica* Hansen (Crustacea) from oceanic, mixed oceanic-coastal, and coastal waters of British Columbia to experimental changes in temperature and salinity. Jour. Exp. Mar. Biol. Ecol. 10:29-40.

Euphausids from coastal waters of Saanich Inlet show a general but small decrease in oxygen uptake with decreased salinity. *E. pacifica* can withstand 21^{o}/oo S at 5, 10, or 15 C in summer, and at 5 or 10 C in winter with little reduction in oxygen uptake. Euphasids from the mixed oceanic-coastal water of Juan de Fuca Strait showed a slight immediate reduction in O_2 uptake with initial dilution from 34^{o}/oo and then no further reduction until a critical low salinity is reached. The lowest salinities tolerated by Juan de Fuca Strait euphausids was 24^{o}/oo. All died at 21^{o}/oo when acclimation temperature was 15 C. Open-ocean euphausids demonstrate independent oxygen uptake in the salinity range 34 to 24^{o}/oo. There is an effect in 24^{o}/oo at 15 C and perhaps also at 10 C for winter animals. None survived 21 ^{o}/oo S regardless of temperature of elevation. Only animals from coastal waters of Saanich Inlet reflected the increased temperature regime from February to June by a larger increase in respiration between 10 and 15 C in winter as opposed to summer.

1624. Glooschenko, W.A. 1969. Accumulation of ^{203}Hg by the marine diatom *Chaetoceros costatum*. Jour. Phycol. 5:224-226.

Dividing and nondividing cell populations of *C. costatum* were placed in light; nondividing populations were also placed in the dark, and one population was killed by formalin. No difference in Hg-203 uptake was seen in nondividing cells in the light and in the dark, but dead cells accumulated about 2 times as much Hg-203 as living cells, presumably by surface adsorption. Dividing cells in light accumulated Hg-203 longer than did nondividing cells, suggesting the possibility of some active uptake of Hg.

1625. Goettl, J.P. Jr., J.R. Sinley and P.H. Davies. 1973. Study of the effects of metallic ions on fish and aquatic organisms. Job Progress Report. State of Colorado Dept. Nat. Res. Job 6 Proj. No. F-33-R-8: 23-115.

On basis of studies reported herein, many of a preliminary nature, authors recommend that maximum acceptable toxicant concentrations for rainbow trout be set at 135 to 250 µg/l for Zn, 12 to 19 µg/l for Cu, 4 to 8 µg/l for Pb, and 0.09 to 0.16 for Ag.

Threshold toxicity levels of Pb, Zn, and Cu to stoneflies *Pteronarcys californica*, were 19.2, 13.6 and 10.1 mg/l respectively. LC-50 values of Pb and Cu to mayflies *Ephemerella grandis*, were 3.5 and 0.2 mg/l, respectively. Both species of insects accumulated these metals in a predictable manner.

1626. Goldberg, E.D. 1952. Iron assimilation by marine diatoms. Biol. Bull. 102:243-248.

Using radioactive iron, author found that *Asterionella japonica* utilized only particulate and/or colloidal iron as a growth nutrient, whereas ionically complexed ferric ion as citrate, ascorbate, or artificial humate was not available for uptake. A minimal content of Fe/cell needed for further division was established as 10×10^{-8} uM/l, or 5.6×10^{-9} mg/l. The ratio of minimal iron to minimal phosphate was determined to be 3.6, which agrees substantially with the Fe/P ratio in natural plankton samples.

1627. Goldberg, E.D. 1957. Biogeochemistry of trace metals. Geol. Soc. Amer. Memoir 67(1):345-358.

General aspects of chemistry of trace metals in marine life are discussed including biochemistry of uptake, metal ratios and paleoecological aspects of marine biogeochemistry. From previously published data, author concludes: (1) heavy metals are concentrated by marine organisms from seawater (2) trace metals are retained by organisms by strong chemical bonds (3) concentration factors vary between species and (4) relative concentration factors for metals parallel stability of metal ions with ligands. Metals discussed include Ca, Sr, V, Y, Ni, Co, Zn, Ti, Zr, Mg, Cr, Mo, Mn, Fe, Cu, Ag, Au, Cd, Ga, Tl, Ge, Sn, Pb, As, Sb, Bi, Pd, Ba and Ra. Organisms mentioned include algae, tunicates, molluscs, coelenterates, sponges, sharks, protozoa, and crustacea.

1628. Goldberg, E.D. 1962. Elemental composition of some pelagic fishes. Limnol. Oceanog. 7(Suppl.):72-75.

Concentration sites of fission products encountered when disposing of radioactive wastes were determined in various species of commercially important fishes: albacore, yellowfin tuna Neothunnus macropterus, skipjack tuna, and anchovetta Engraulis ringenus. Manganese, Cu, Ni, and Zn concentrate in viscera with highest levels, in % composition of ashed samples, being 0.014, 0.075, 0.24, and 1.04, respectively. Calcium and Sr accumulate in bone and cartilage with highest concentrations being 50 and 0.2, respectively. Transition elements were most abundant in viscera except heart, flesh, and skin (Zr up to 0.27%, Ti up to 0.032%, and V up to 0.055%); these were least abundant in bony tissues. Rubidium and Cs were expected to be at least as strongly assimilated by organisms relative to Na as was K. Concentration levels for Na, K, P, Mg, Si, Al, Fe, Ba, B, Cr, Pb, Mo, and Ag, as well as whole animal compositions, are also given.

1629. Goldberg, E.D. (No publ. date given) Review of trace element concentrations in marine organisms. Vol. I and Vol. II. Published by Puerto Rico Nuclear Center Mayaguez, P.R. 535 pp.

This is a limited distribution edition of an annotated bibliography of selected technical articles on stable and radiolabelled species found in marine organisms. Almost all articles were published between 1958 and 1965. For each article, data are presented in tabular and graphical form and arranged by element. Elements include Al, As, Ba, Be, B, Cd, Ca, Ce, Cs, Cr, Co, Cu, Ga, Au, Fe, Pb, Li, Mg, Mn, Mo, Ni, Nb, Pu, K, Ra,Re, Rb, Ru, Sc, Si, Ag, Na, Sr, Ta, Th, Sn, Ti, W, U, V, Y, Zn, Zr, Dy, Eu, Ho, La, and Pr.

1630. Goldberg, E.D., W. McBlair, and K.M. Taylor. 1951. The uptake of vanadium by tunicates. Biol. Bull. 101:84-94.

Vanadium contents of California ascidians in mg/kg dry wt were: 0 for *Styella montereyensis* and *S. bonharti*, 475 for *Euherdmania clauiformis*, and 100 for *Ciona intestinalis*. For various body parts of *C. intestinalis*, V content in mg V/kg dry wt was 0 for tunic, mantle, heart, excurrent siphon, esophagus, branchial basket, 76 for ovary, 109 for incurrent siphon, 911 for anterior gut, 178 for posterior gut, and 248 for stomach, leading to a total level of 95 mg V/kg dry wt. V content of fecal pellets and mature eggs extruded into peribranchial cavity varied between 0 and 800 mg/kg. In *Ascidia ceratodes*, phosphate will inhibit uptake of V. Authors suggest that V in ionic form rather than colloidal V is adsorbed by tunicates. Dietary requirement of V for tunicates could be met by direct adsorption of particulates from seawater, with an efficiency of assimilation estimated at 2½% for unfed animals.

1631. Gorgy, S., N.W. Rakestraw, and D.L. Fox. 1948. Arsenic in the sea. Jour. Marine Res. 7:22-32.

The total arsenic present in seawater varied from 0.2 to 0.5 ug atom/l. Of this, from 50 to 60% is in the form of arsenite, and from 8 to 16% each of arsenate, dissolved organic arsenic, and arsenic in the suspended particulate matter. The relative proportion of arsenite was slightly greater in the upper levels. Arsenic content, in mg/kg, for various species of marine biota were determined: 0.121 wet wt in octopus (tentacles) *Octopus bimaculatus*; 0.085 wet wt in mussel *Mytilus edulis*; 1.26 dry wt in the echinoderm *Pisaster ochraceus*; and 17.3 dry wt in brown kelp *Macrocystis pyrifera* (this is about 1000 X the concentration of As in seawater).

Sea anemones which originally contained 6.6 mg As/kg dry wt were kept in two aquaria to which increasing amounts of arsenite and arsenate were added periodically. Individuals were removed occasionally for analysis; concentration of As increased more rapidly in those exposed to arsenite. All anemones died after exposure to concentrations up to 90 ug As^{3+}/l, at which point they contained 21.2 mg As/kg dry wt. Animals exposed to arsenate concentrations up to 160 ug As^{+5}/l were alive and contained only 10 mg As/kg. Anemones dying from As^{+3} exposure were analyzed for arsenic: 91% of the As was in the protein fraction, 1% in the lipid fraction, and 7% soluble inorganic arsenic.

1632. Gould, E., R.S. Collier, J.J. Karolus and S. Givens. 1976. Heart transaminase in the rock crab, *Cancer irroratus*, exposed to cadmium salts. Bull. Environ. Contamin. Toxicol. 15:635-643.

Crabs exposed for 4 days to 1 mg/l Cd^{2+} as chloride salt exhibited mean aspartate aminotransferase (AAT) activity in heart muscle preparation of 2963 units (1 AAT unit = change in absorbance of 0.001/

min/mg protein); control value was 1784 units. When crabs were exposed to 1 mg/kg Cd as the nitrate salt, heart AAT was depressed at 1510 units, suggesting that Cd is more toxic as the chloride than nitrate. Mean residual AAT activity in frozen and thawed crab heart preparations exposed to 1 mg/l Cd as $CdCl_2$ were 64% of original activity while controls and those exposed to 1 mg/l Cd as $Cd(NO_3)_2$ exhibited 31 and 19%, respectively.

1633. Grant, F.B., P.K.T. Pang and R.W. Griffith. 1969. The twenty-four-hour seminal hydration response in goldfish (Carassius auratus)-I. Sodium, potassium, calcium, magnesium, chloride and osmolality of serum and seminal fluid. Comp. Biochem. Physiol. 30:273-280.

Spermiation was induced in goldfish by an IP injection of carp pituitary extract. Seminal fluid levels of major electrolytes were unchanged from control values, in mg/l, of 2369 for Na, 2153 for K, 68 for Ca, and 42 for Mg, giving a total osmolality of 289 m Osm/l. Serum from treated goldfish, however, contained 3333 mg/l Na and 580 mg/l K and these were significantly different from control levels of 3255 Na and 77 K. Calcium and Mg values of serum were the same as control levels of 126 for Ca and 35 mg/l for Mg. In whole testis, an increase of K from 34 to 49 g/kg dry wt and Na from 29 to 53 g/kg was greater than could be accounted for by addition of seminal fluid.

1634. Gray, J.S. 1974. Synergistic effects of three heavy metals on growth rates of a marine ciliate protozoan. In Vernberg, F.J. and W.B. Vernberg (eds.). Pollution and Physiology of Marine Organisms. Academic Press, N.Y.: 465-485.

Using factorial experimental designs, the short-term growth rate of a ciliate protozoan Cristigera was optimum at $27^{o}/oo$ salinity and 16 C. Significant interaction occurred between salinity and temperature on growth rates. Mercury ($HgCl_2$) at a concentration of 0.005 mg/l reduced growth rate by 12%, lead ($Pb(NO_3)_2$) at 0.3 mg/l by 11%, and zinc ($ZnSO_4$) at 0.25 mg/l by 14%. On mixing these concentrations, growth rate was reduced by 67%, whereas on an additive basis 37% was predicted. Regression equations and graphical response surfaces are shown for 2 and 3 factor interactions; some interactions were antagonistic, others synergistic. Toxic effects were lower, or as low as, the most sensitive known organisms suggesting Cristigera as a potentially useful test organism. Consideration of adaptation problems, robustness and ecological roles of organisms, is given in relation to the selection of species for use in toxicity testing programs.

1635. Gray, J.S. and R.J. Ventilla. 1971. Pollution effects on micro- and meiofauna of sand. Marine Poll. Bull. 2:39-43.

Effects of Hg, Pb, and Cu on the bacterivorous sediment-living ciliate Cristigera was examined. Mercuric chloride was lethal at 0.02 mg/l. Lead, as $Pb(NO_3)_2$, reduced growth rate at >0.3 mg/l but did not inhibit growth at 0.1 to 0.3 mg/l. Copper had no effect at 2 mg/l, but this was attributed to absence of ionic Cu due to complexion or chelation with organic matter. Significant interactions between lead/mercury and copper/mercury imply synergism.

1636. Green, F.A., Jr., J.W. Anderson, S.R. Petrocelli, B.J. Presley and R. Sims. 1976. Effect of mercury on the survival, respiration and growth of postlarval white shrimp, Penaeus setiferus. Marine Biology 37:75-81.

LC-50 (96 h) value of mercury to shrimp of 17 ug/l was unaffected by size of shrimp, over range of 7 to 35 mm, or pre-exposure to 0.5 and 1.0 ug Hg/l for 57 days. Exposure for 60 days to 0.5 and 1.0 ug Hg/l did not affect respiration, growth, or molting rates of postlarval shrimp.

1637. Greenaway, P. 1971. Calcium regulation in the freshwater mollusc Limnaea stagnalis (L.) (Gastropoda: Pulmonata). II. Calcium movements between internal calcium compartments. Jour. Exp. Biol. 54(3):609-620.

Calcium, in g/kg wet wt, of selected tissues were: shell 382, blood 0.2, total wet tissue 0.9, mantle 2.0, digestive gland 1.5 and reproductive organs 0.6. Ca-45 absorbed from medium appeared first in blood, then shell and other tissues; uptake plateaued at 20 hrs for blood and 30 hrs for total fresh tissue. About 30% of tissue Ca and about 20% of mantle Ca exchanged with blood Ca; continual exchange between shell and blood Ca occurred. During net Ca loss from L. stagnalis, a net movement of Ca from shell to blood occurred at a rate similar to rate of net loss; a similar pattern was observed during net Ca uptake.

1638. Greenaway, P. 1972. Calcium regulation in the freshwater crayfish Austropotamobius pallipes (Lereboullet). I. Calcium balance in the intermoult animal. Jour. Exp. Biol. 57(2): 471-487.

Mean Ca influx and efflux on intermoult crayfish in artificial tapwater were 0.56 (influx) and 0.92 mg Ca/kg/hr. Ca uptake was against a small electrochemical gradient; part of influx occurred by active transport. Most of Ca loss occurred across gills; urine contribution was small. Ca-depleted animals showed only a small drop in haemolymph Ca concentration; Ca uptake was not significantly increased by depletion.

1639. Greenaway, P. 1974. Total body calcium and haemolymph calcium concentrations in the crayfish *Austropotamobius pallipes* (Lereboullet). Jour. Exp. Biol. 61:19-26.

Variations in concentration of Ca in haemolymph and total body Ca in crayfish show that haemolymph Ca concentration was independent of both sex and body size. During premoult, Ca level of haemolymph rose from 11.8 to 15.0 mM/l. After moult, Ca level remained high during stages A and B (maximum of 15.6 mM/l, stage A) but declined to the intermoult level during stage C. Total body Ca was directly proportional to fresh body wt. Concentration of magnesium in haemolymph varied between 4.2 to 0.56 mM-Mg/l, and showed little correlation with body wt. Ratio of total Ca:Mg was 53:1, and exoskeleton Ca:Mg was 44:1, both largely independent of body size. Haemolymph Ca:Mg ratio did vary with size, having a mean of 7.8:1. Concentrations of Ca in haemolymph (in mM/l) of freshwater crustacea, derived from numerous studies, are given for water Ca levels of 0.038 to 2.75 mM/l: *A. pallipes* 6.5 - 18.0, *Astacus astacus* 6.5 - 15.2, *Orconectes limosus* 6.5 - 13.5 (and up to 20.5 mM/kg H_2O), *Potamon niloticus* 12.7, *Eriocheir sinensis* 11.5, and *Gammarus pulex* 5.85 - 7.65. The marine crustacea *Carcinus* had a similar level of 12.4 mM/l. In contrast, calcium concentrations in haemolymph of freshwater molluscs was reduced: *Limnaea stagnalis* 4.9, *Anodonta* 6.0, and *Viviparus viviparus* 5.7.

1640. Greenaway, P. 1974. Calcium balance at the premoult stage of the freshwater crayfish *Austropotamobius pallipes* (Lereboullet). Jour. Exp. Biol. 61:27-34.

The premoult stages are characterized by a net loss of Ca which increases with development to a maximum of 0.83 μmoles/g/h. Net loss of Ca in urine at later stages is approximately 0.006 μmoles/g/h, which represents only a small fraction of observed Ca loss. The concentration of ionized Ca in haemolymph does not increase during premoult stage although there is an increase in complexed Ca (7.4 mM/l ionized, 8.8 mM/l complexed). The electrochemical gradient across the body surface is similar to that at the intermoult stage and favors Ca outflux. Possible routes for Ca net loss are discussed, and a mechanism for elimination of Ca proposed.

1641. Greenaway, P. 1974. Calcium balance at the postmoult stage of the freshwater crayfish *Austropotamobius pallipes* (Lereboullet). Jour. Exp. Biol. 61:35-45.

Net uptake of Ca by *Austropotamobius* begins 15-30 min after moult and rapidly reaches a maximum (0.08 mg/g/h at 10 C); this is maintained throughout stages A and B. At stage C_1 rate of net uptake falls sharply to a lower level which is gradually reduced until equilibrium is reached at C_4. The uptake mechanism is near-saturated at 16 mg-Ca/ℓ and half-saturated at 5.2 mg-Ca/ℓ. The concentration of ionized Ca in haemolymph ($\sim$280 mg/ℓ) remains unchanged during intermoult cycle, although level of non-ionized Ca is greater during stages D_4 and A_1 ($\sim$560 mg/ℓ) than at other stages. In absence of external HCO_3^-, net uptake is reduced by 60%; uptake in the remaining 40% proceeds through use of metabolic CO_2.

1642. Greenaway, P. 1976. The regulation of haemolymph calcium concentration of the crab, *Carcinus maenas* (L.). Jour. Exp. Biol. 64:149-157.

Carcinus was able to maintain Ca balance after acclimation in dilute seawater (35-100%), but not in low calcium seawater. Of total haemolymph Ca (9.54 mM), 71% was ionic as compared to 91% (9.9 mM) in seawater. On acclimation to dilute seawater, Ca activity of haemolymph was greater than medium, the difference being maintained by active Ca uptake. *Carcinus* is highly permeable to Ca^{2+}, influx from seawater being 0.513 μmoles/g/h and time constant for Ca influx 4.3 hr. Ca space represented $\sim$25% wet body wt independent of body size or salinity of acclimation medium.

1643. Greenfield, S.S. 1942. Inhibitory effects of inorganic compounds on photosynthesis in *Chlorella*. Amer. Jour. Bot. 29: 121-131.

Under light intensity of 22,000 lux, photosynthesis in *C. vulgaris* was inhibited 50% by 0.0008 g/l $CuSO_4$, 31 g/l $CoSO_4$, 32 g/l $ZnSO_4$, 53 g/l KCl, and 119 g/l $NiSO_4$. These concentrations did not produce residual effects on growth when cells were transferred to a culture medium. Photosynthesis inhibition by $MgSO_4$, $MnSO_4$ or KNO_3 occurred at concentrations which caused osmotic stress. Treatment with 6.8 mg $HgCl_2$/l completely inhibited photosynthesis but 2.7 mg $HgCl_2$/l had no effect; 27 mg $HgCl_2$/l impaired apparent health for 3 days after innoculation into culture medium. Only the dark reaction was retarded by $ZnSO_4$, $NiSO_4$, and KCl. Effect of $CuSO_4$, H_3BO_3, and KI was retardation of dark reaction and a lesser inhibition of the light stage; $CoSO_4$ depressed both the dark and photochemical stages of photosynthesis.

1644. Greenwald, L., L.B. Kirschner, and M. Sanders. 1974. Sodium efflux and potential differences across the irrigated gill of sea water-adapted rainbow trout (*Salmo gairdneri*). Jour. Gen. Physiol. 64:135-147.

Sodium extrusion and potential difference (TEP) were measured across gills of seawater-adapted trout using a gill-irrigation system of small volume. Na efflux was usually between 100-250 μ eq/100g/h, 10 X faster than freshwater-adapted trout, but slower than reported for any other marine teleost. When the external medium was changed from SW to FW, Na efflux was reduced to about 25% of initial value, and TEP was reduced by 40-50 mV. Addition of either Na$^+$ or K$^+$ in SW concentrations reversed the changes; Na efflux increased and the gill repolarized. Electrical behavior and Na efflux in irrigated trout gill is the same as reported for unanaesthetized free-swimming fish of other species. Thus, irrigated gill provides an adequate model for studying mechanisms of Na extrusion in marine teleosts.

1645. Greig, R.A. 1975. Comparison of atomic absorption and neutron activation analyses for determination of silver, chromium and zinc in various marine organisms. Anal. Chem. 47:1682-1684.

Neutron activation analyses and atomic absorption were used to determine Ag, Cr and Zn levels in marine biota. Silver concentration, in mg/kg wet wt ranged from 0.39 to 1.3 in muscle of surf clam *Spisula solidissima*; 0.21 in muscle to 6.3 in digestive diverticulum of rock crab *Cancer irroratus*; 0.53 in gills to 32.0 in digestive diverticula in channeled whelk *Busycon canaliculatum*; 0.37 to 0.54 in muscle of lobster *Homarus americanus*; and 0.18 to 0.32 in liver of white hake *Urophycis tenuis*. Silver concentration in zooplankton ranged from 1.1 to 3.1 mg/kg dry wt. Chromium concentration, in mg/kg wet wt, ranged from 0.22 to 0.68 in muscle of summer flounder *Paralichthys dentatus*; 0.24 in dig. div. to 4.2 in gills of channeled whelk; 0.74 to 2.7 in muscle of surf clam; and 0.20 to 0.59 in liver of white hake. Concentration of Cr in plankton ranged from 0.48 to 53.0 mg/kg dry wt. Zinc concentration, in mg/kg wet wt, ranged from 2.9 to 3.8 in muscle of white hake; 4.2 to 4.4 in muscle of yellowtail flounder *Limanda ferruginea*; 23 to 28 in muscle of windowpane flounder *Scopthalmus aquosus*; 35 to 43 in digestive diverticulum of rock crab; and 25 in muscle to 2600 in dig. div. of whelk.

1646. Greig, R.A., B.A. Nelson and D.A. Nelson. 1975. Trace metal content in the American oyster. Marine Poll. Bull. 6:72-73.

Two groups of *Crassostrea virginica* containing significantly different levels of copper and cadmium were induced to spawn. Eggs from both groups contained the same amount of Cu at 27.8 and 28.9 mg/kg dry wt; in both groups Cd content was below detectable limits of <1.6 mg/kg dry wt. These similar concentrations suggest that amount of metal transferred from adult to egg is fairly constant and not dependent on level available in adults. Silver, lead and zinc concentrations were also determined; levels of these metals were similar for adult and eggs of the two groups examined.

1647. Greig, R.A., D.R. Wenzloff, and J.B. Pearce. 1976. Distribution and abundance of heavy metals in finfish, invertebrates and sediments collected at a deepwater disposal site. Marine Poll. Bull. 7:185-187.

Concentrations were determined of Ag, As, Cd, Cr, Cu, Hg, Ni, Pb and Zn in 4 species of deepwater demersal finfish, one species of benthic invertebrate (red crab *Geryon quinquedens*), and 3 species of pelagic fish collected from the area of a deepwater disposal site in the New York Bight. Highest values of Cd, Cu, Ni, Pb and Zn were in livers of *Nematonurus armatus* at 1.3, 4.8, 0.8, 1.6 and 50.0 mg/kg wet wt, respectively. Highest values of Ag, As and Hg were in muscle of *Antimora rostrata* at 0.1, 21.1 and 0.6 mg/kg wet wt, respectively. The highest value of Cr at 1.1 mg/kg wet wt was in liver of *Holosauropsis macrochir*. These 3 species are generally regarded as bottom dwellers. Comparison of metal content of red crab with coastal green crab *Carcinus maenas*, showed that Ni was significantly higher in *Carcinus* but other metals were the same. Comparison of Hg content in deepwater fish taken off Cape Hatteras with one collected 90 years previously showed no significant variations with area or time, suggesting that other metal levels are normal for this group. Deepwater bottom dwelling teleosts when compared to fish species collected from the continental shelf contain lower overall metal content in muscle and liver.

1648. Greig, R.A., D. Wenzloff and C. Shelpuk. 1975. Mercury concentrations in fish, North Atlantic offshore waters—1971. Pestic. Monit. Jour. 9:15-20.

Mercury concentrations in muscle of 41 species of fish and elasmobranchs collected from North Atlantic offshore waters in 1971 ranged from <0.05 to 0.35 mg/kg wet wt, with an average of 0.154 mg/kg. Fish liver Hg concentrations ranged from <0.05 to 0.42 mg/kg wet wt. Mercury levels in the 9 plankton samples taken were less than 0.05 mg/kg wet wt. Mercury concentrations in lobster *Homarus americanus* were 0.31 and 0.60 mg/kg in muscle and liver, respectively. Mercury content was <0.05 to 0.06 mg/kg in whole squid *Illex illecebrosas*, and <0.05 in edible muscle of scallops *Placopecten magellanicus*.

1649. Griffith, R.W. 1974. Environment and salinity tolerance in the genus Fundulus. Copeia (2):318-331.

A comparison was made of environmental salinities, ability to survive in freshwater and upper salinity tolerance for over 20 species of the teleost genus Fundulus. All species occur, at times, in freshwater and are able to survive in this medium in the laboratory. Species found in brackish environments have upper salinity tolerances ranging from 74-114°/oo, while most species characteristic of freshwaters are unable to survive in salinities above 29°/oo. Notable exceptions are F. zebrinus, an inland species commonly found in saline waters; F. diaphanus, a freshwater form which often enters dilute brackish estuaries; and F. waccamensis, a Pleistocene lacustrine derivative of F. diaphanus. Since brackish-water species are tolerant of life in freshwater while the reverse is not the case, it is suggested that freshwater species of Fundulus were derived from fully euryhaline ancestors which gradually lost ability to live in seawater during extended isolation from brackish or marine environments.

1650. Griffith, R.W., M.B. Mathews, B.L. Umminger, B.F. Grant, P.K.T. Pang, K.S. Thomson and G.E. Pickford. 1975. Composition of fluid from the notochordal canal of the coelacanth, Latimeria chalumnae. Jour. Exper. Zool. 192:165-172.

Notochordal canal fluid of Latimeria was analyzed for major inorganic and organic constituents and compared with blood serum from the same fish. Lower levels of Na, Mg, Ca, bicarbonate, sulfate, total carbohydrates, glucose, lactate, cholesterol, bound phosphate and total proteins were found in notochordal fluid than in serum, whereas K, chloride, urea, trimethylamine oxide, and total free amino acids were higher and inorganic phosphorus essentially identical. Osmolarity of notochordal fluid (1058 mOsm) exceeds that of serum (942 mOsm). A whitish precipitate in the fluid consisted of a matrix of fibers 100 Å in diameter and of indefinite length. It resembled a sialoglycoprotein in composition and was stabilized by disulfide bonds. The fluid contained cellular debris.

1651. Griffith, R.W., B.L. Umminger, B.F. Grant, P.K.T. Pang, L. Goldstein and G.E. Pickford. 1976. Composition of bladder urine of the coelecanth, Latimeria chalumnae. Jour. Exp. Zool. 196:371-380.

Inorganic cation levels of urine from bladder of a live Latimeria were compared with serum levels from same fish. Content in urine in mg/l, was 4209 for Na, 330 for K, 66 for total Ca, and 727 for Mg. Osmolarity is identical in serum and urine. Mg, PO_4, SO_4, creatine, creatinine and glucoronate were highly concentrated in urine; Cl^-, bicarbonate, protein and glucose were lower in urine than in serum. Total Ca levels in urine were less than serum total Ca. Urea levels were identical in both fluids.

1652. Griffith, R.W., B.L. Umminger, B.F. Grant, P.K.T. Pang and G.E. Pickford. 1974. Serum composition of the coelacanth, Latimeria chalumnae Smith. Jour. Exp. Zool. 187:87-102.

Blood serum from a living coelacanth contained 6300 mg Na/l, 235 mg K/l, 127 mg Mg/l, and 198 mg Ca/l. Cl^-, HCO_3^-, PO_4, SO_4, and organic concentrations were also determined. Osmolarity of serum (932 mOsm/l) was lower than seawater (1035 mOsm/l), indicating that coelacanths are hypoosmotic to medium in contrast to elasmobranchs, holocephalians and hagfish. Evolutionary implications of Latimeria serum chemistry to that of other marine fishes are discussed.

1653. Gromov, V.V. and V.I. Spitsyn. 1974. Assimilation of plutonium, ruthenium and technetium by phytoplankton. Acad. Sciences USSR, Hydrobiology 215(1):214-217.

Accumulation of Pu-239, Ru-106, and Tc-99 by the marine green algae Platymonas viridis was observed under different conditions of illumination during a 6-day period. There was little or no accumulation of Tc-99 under the conditions of this study. On a live wt basis Ru was accumulated to a greater degree than Pu (40% of total isotope available vs 16%). Similar results were obtained with mixed phytoplankton cultures; uptake of both was apparently unaffected by light intensity.

1654. Gromov, V.V. and V.I. Spitsyn. 1974. Influence of phytoplankton on the physicochemical state of Pu^{239}, Ru^{106}, Tc^{99}, and Co^{60} in seawater. Acad. Sciences USSR, Hydrobiology 215(2):451-453 (Doklady Biol. Sci. 215:151-153).

Effect of Platymonas viridis on sorption properties of Pu-239, Ru-106, Tc-99 and Co-60 by deep water red clays was studied. Sorption is reduced by factors of about 3000 for Pu-239, 2500 for Ru-106, 15 for Tc-99 and zero for Co-60. Sorption of all isotopes was inversely related to particle size (surface area) of adsorbing substrate.

1655. Gross, R.E., P. Pugno and W.M. Dugger. 1970. Observations on the mechanism of copper damage in Chlorella. Plant Physiol. 46: 183-185.

Addition of excess copper (about 63 mg/l Cu) to non-growing cells of a normal green alga caused reduction in total pigments and inhibition of photosynthesis. Within 5 to 10 min after addition of 6 mg/l $CuSO_4$, chlorophyll-less yellow and white mutant strains of the same alga showed a rise in non-specific absorption and a decrease in packed cell volume. Respiration rose from 3.6 to 7.9 ul O_2/mg dry wt/hr in the yellow strain. Glutathione prevented all copper-induced changes, whereas $MnCl_2$ protected only partially. Selective inhibition of some responses to copper was observed when O_2 was absent or antitoxicants present.

1656. Gross, W.J. 1957. An analysis of response to osmotic stress in selected decapod crustacea. Biol. Bull. 112:43-62.

Emerita, *Callianassa*, *Upogebia*, *Cancer antennarius*, *C. gracilis* and *Pugettia* cannot regulate osmotically and from lack of tolerance are generally stenohaline. *Pachygrapsus*, *Birgus*, *Hemigrapsus* and *Uca* can regulate osmotically in concentrated and dilute seawater. *Hemigrapsus* is the weakest hypoosmotic regulator of the 4 species, able to regulate up to 33% for 20 hours in 150% SW. Where osmotic regulation occurs, it is established immediately and sustained perfectly in moderate stresses (75% to 125% SW) for a few hours. Regulation diminishes gradually until equilibrium blood concentration is reached (≤24 hrs). Fluctuations occasionally occur later when extreme stresses are imposed. Solute space volumes were calculated as 40% for *Emerita*, 54% for *Pachygrapsus*, and 50% for *Birgus*. Concentration changes occurring in blood of *Pachygrapsus* and *Emerita* are caused by salt more than by water exchanges. There is a dynamic flux of salt and water in gill chambers of *Pachygrapsus*, furnishing further evidence that gills are osmo-regulatory organs. Osmotic regulating crustaceans *Cambarus*, *Pachygrapsus*, *H. nudus*, and *H. oregonensis* have exoskeletons 1/3 less permeable than the non-regulators, *Cancer gracilis*, *C. antennarius* and *Pugettia*. *Pachygrapsus*, *Uca*, *H. nudus* and *oregonensis* sustain greater osmotic gradients when greater osmotic stresses are imposed, the gradient between blood and external medium being 45-50% SW when medium concentration is 25% SW. Two species of *Hemigrapsus* are weak regulators in small stress (>75% SW) but osmoregulatory behavior increases as stress does. A sensitivity to absolute salinities is suggested. Consumption of O_2 by *Uca* in 50% SW was 108% of that in 100% SW, and in tap water it was about 135% of the amount of O_2 consumed in 100% SW. Author noted that increases in metabolism were not direct reflections of increased osmotic work but of muscular activity due to resistance to osmotic stress.

1657. Gryzhankova, L.N., G.N. Sayenko, A.V. Karyakin and N.V. Laktionova. 1973. Concentration of some metals in the algae of the Sea of Japan. Oceanology 13:206-210.

Metal levels, in mg/kg dry wt, of 9 species of red and brown algae ranged from 189 to 886 for Fe, 16 to 455 for Mn, 2 to 7 for Cu, 8 to 27 for Ni, 2 to 147 for Co, 5 to 147 for Ti, 4 to 24 for V, and 2 to 14 for Cr. For 3 species of green algae, metal contents were 82 to 596 for Fe, 5 to 805 for Mn, 3 to 8 for Cu, 5 to 31 for Ni, 2 to 31 for Co, 1 to 41 for Ti, 4 to 21 for V, and 1 to 6 for Cr.

1658. Guary, J.-C., M. Masson and A. Fraizier. 1976. Etude preliminaire, *in situ*, de la distribution du plutonium dans differents tissus et organes de *Cancer pagurus* (Crustacea: Decapoda) et de *Pleuronectes platessa* (Pisces: Pleuronectidae). Marine Biology 36:13-17. (In French, English summary)

Plutonium levels in pCi/kg wet wt of crab were 102 for gills, 2.2 for exoskeleton, 0.5 for meat, 0.5 for gonads, 0.4 for remainder, 1.9 for hepatopancreas, 2.2 for gastro-intestinal tract, 0.3 for hemolymph, with a whole organism value of 3.5. Plaice *P. platessa* levels in pCi/kg wet wt, were 2.3 for gills, 0.6 for skin, 64.2 for gastrointestinal tract, 0.5 for liver, 2.9 for spleen, 2.2 for kidney, 0.9 for gonads, 0.1 for meat, 0.1 for remainder, with a whole organism value of 3.1. Data indicate contamination of crab by surface absorption of gills and exoskeleton; in plaice, feeding processes are implicated. Authors conclude that edible parts of these species, particularly the flesh, do not constitute an important source of Pu contamination to man.

1659. Gueguenìat, P., P. Bovard, and J. Ancellin. 1969. Influence de la forme physico-chimique du ruthenium sur la contamination des organismes marins. C.R. Acad. Sci. Paris, t. 268:976-979.

Nitrosyl-ruthenium compounds produced by irradiated waste treatment reclamation and subsequently discharged into marine environments are either soluble, insoluble or "intermediate"—the exact percentages vary according to the quantity of suspended materials in water. Field studies with marine algae (*Chondrus crispus*, *Corallina officinalis*), coelenterates (*Actinia equana*), molluscs (*Mytilus*), and crustaceans (*Leander serratus*) suggest that particulate ruthenium species are taken up in greatest concentration. For example, algae exhibit concentration factors between 750 and 3000 for particulate Ru, and 80 to 120 for soluble forms.

1660. Gunter, G. 1955. Mortality of oysters and abundance of certain associates as related to salinity. Ecology 36:601-605.

Author concludes that number of species of marine animals declines along salinity gradients towards freshwater, and that comparatively high oyster mortality observed at higher salinities were due to greater incidence of predation and parasitism.

1661. Gunter, G. 1967. Vertebrates in hypersaline waters. Publs. Inst. Mar. Sci. Univ. Tex. 12:230-241.

Hypersaline areas, including lagoons, pools and shore ponds, and salt flats or salinas, occur only along sea coasts in arid or semiarid zones, and have salinities ranging from 45 to $206^{o}/oo$. Brine flies *Ephydra*, are found in waters up to 140 and $150^{o}/oo$, a few fish can survive at $100^{o}/oo$, and *Cyprinodon variegatus*, a euryhaline teleost, has been recorded at $142^{o}/oo$. Fauna of hypersaline lagoons is predominantly derived from nearby brackish waters rather than the sea.

1662. Hagen, A. and A. Langeland. 1973. Polluted snow in southern Norway and the effect of the meltwater on freshwater and aquatic organisms. Environ. Poll. 5:45-57.

In polluted snow and ice-trapped and surface water of southern Norwegian lakes and brooks, maximal metal contents, in ug/l, were: Cd 10; Cu 15; Pb 77; Zn 120; Fe 180; Ca 1300; Mg 700; and Mn 35. In some cases pH values near 3.34 were observed; in those instances bottom fauna, consisting mostly of chironomids, were depleted. Authors concluded that high Zn levels and low pH are also potentially hazardous to fishes.

1663. Hagiwara, S., H. Hayashi and K. Takahashi. 1969. Calcium and potassium currents of the membrane of a barnacle muscle fibre in relation to the calcium spike. Jour. Physiol. 205:115-129.

Membrane currents in giant muscle fiber of *Balanus nubilus* are composed of two components: an early transient current, and a late outward component. Early transient current consists of two parts: an inward current, carried by Ca ions and suppressed by conditioning depolarization, cobalt ions, and decreased external Ca level; and an outward current, carried by K ions, and suppressed by procaine, but not by conditioning depolarization or decreased external Ca levels. Authors concluded that early conductance increase of muscle fiber membrane occurred only with Ca but not K, although membrane potential at spike peak was determined by both.

1664. Hajj, H. and J. Makemson. 1976. Determination of growth of *Sphaerotilus discophorus* in the presence of manganese. Appl. Environ. Microb. 32:699-702.

Cultures of Sphaerotilus, a filamentous bacteria, to which 0.005% $MnSO_4$ was added, exhibited reduced growth and biomass when compared to controls. Manganese oxidation occurred only during the latter portion of logarithmic growth and into the stationary phase.

1665. Hall, J.W., J.C. Arnold, W.T. Waller, and J. Cairns, Jr. 1975. A procedure for the detection of pollution by fish movements. Biometrics 31:11-18.

An "alarm" system using fish movement has been developed to provide rapid information concerning accidental spills of pollutants. Statistics used to transform data of a non-stationary stochastic process to a stationary one are given. Using Zn as the pollutant, tests indicate that bluegill sunfish Lepomis macrochirus, will show abnormal behavior patterns within 6 hrs at 13.32 mg/l, but not for 80 hrs at 3.65 mg/l.

1666. Hara, T.J., Y.M.C. Law and S. MacDonald. 1976. Effects of mercury and copper on the olfactory response in rainbow trout, Salmo gairdneri. Jour. Fish. Res. Bd. Canada 33:1568-1573.

Lowest concentrations of mercury as $HgCl_2$, and copper as $CuSO_4$, that depressed electrical response of trout olfactory bulb to stimulant L-serine within 2 hrs were 0.1 mg Hg/l and 0.008 mg Cu/l. Depression increased with increase in concentration of Cu and Hg, and with exposure time. Recovery was slower with higher concentrations and longer exposure.

1667. Harriss, R.C. 1971. Ecological implications of mercury pollution in aquatic systems. Biological Conservation 3:279-283.

Sources and effects of mercury pollution in aquatic systems are reviewed. In experimental ponds, algae had concentration factors of 200-1200; large plants, 4-2400; invertebrates, 400-8400, and pike in natural waters had CF of 3000. Biomagnification in upper trophic levels is shown in Great Lakes where plankton-feeding fish had levels of Hg from 0.2 to 1.0 mg/kg; top predators, such as walleye, pike and white bass had levels from 1.0 to 2.0 mg Hg/kg. Waterfowl and other fish-eating animals contained up to 20 mg Hg/kg. Low-level Hg pollution may not kill macrofauna, but may seriously deplete planktonic food supply. Organomercury compounds reduced photosynthesis in the marine diatom Nitzchia delicatissima to less than 10% of controls after 24 hr exposure to 0.01 mg/l. These low levels can eliminate plankton with subsequent emigration or death of fish. Behavioral, physiological, genetic and synergistic effects, and need for environmental standards are also discussed.

1668. Harza, T. and L. Matyas. 1976. Seasonal variations of sodium and potassium concentrations in different parts of the frog myocardium. Biol. Bull. 151:306-313.

Respective mean Na and K concentrations, in g/kg wet wt, in heart of frog Rana esculenta, were 2.4 and 0.9 for sinus venosus, 1.7 and 1.1 for atrium and 1.2 and 2.2 for ventricle. Na concentrations varied seasonally; differences between minimum (in winter) and maximum (in summer) values representing 46% (sinus venosus), 30% (atrium), and 34% (ventricle) of spring-autumn values. Although K level in ventricle declined in the second half of the year, other portions of the heart showed no variation with respect to K.

1669. Hassall, K.A. 1963. Uptake of copper and its physiological effects on Chlorella vulgaris. Physiologia Plantarum 16:323-332.

Effects of salts of Ba, Mg, Al, Mn, Zn, Ni, Pb, Fe, Cu, Hg, Ag and Au, upon growth and respiration of C. vulgaris were studied. Significant toxic effects, as % respiration of untreated cells 3 to 5 hrs after addition, were exhibited by Cu at 7 X 10^{-2}M $CuSO_4$ with 97% and 8% respiration in aerated and unaerated flasks. Mercury at 3 X 10^{-4}M $HgCl_2$ showed 10% and 5% respiration (aerated and unaerated); Ag at 2 X 10^{-4}M $AgNO_3$ showed 15% and 14% respiration (aerated and unaerated); and Au at 2 X 10^{-3} $NaAuCl_4$ showed 65% and 2% respiration (aerated and unaerated). Copper was unique in that it was highly toxic when applied under anerobic conditions, but seldom reduced respiration at high concentrations in aerated vessels. Comparison of rates of uptake of copper by living and previously scalded cells, show that dead cells absorb copper extremely rapidly, but that total sorbed is same as when copper itself kills cells by prolonged anaerobic contact. Two-thirds of the copper is firmly retained, even by dead cells, and resists removal by washing. Cells supplied with glucose as energy source grow in higher copper concentrations than cells relying upon photosynthesis.

1670. Hassall, K.A. 1967. Inhibition of respiration of Chlorella vulgaris by simultaneous application of cupric and fluoride ions. Nature 215:521.

In algae C. vulgaris, an alternate respiratory pathway induced by fluoride blockage of the main route was inhibited by $\geq$ 12.7 mg Cu/l.

1671. Hassall, K.A. 1969. An asymmetric respiratory response occurring when fluoride and copper ions are applied jointly to *Chlorella vulgaris*. Physiologia Plantarum 22:304-311.

Algal suspensions, when treated simultaneously with 10^{-2} M $CuSO_4$ and 4 X 10^{-2} M NaF, almost completely cease respiring though the two ions individually have little inhibitory effect. If cells are pretreated with $CuSO_4$ before adding NaF, inhibition of respiration becomes more severe as pretreatment time is lengthened, except at high Cu levels which alone inhibit respiration. When pretreatment is with F ions, inhibition becomes less as pretreatment time is lengthened, with no inhibition at 90 min. In absence of F, Cu content of cells after contact with 9.6 X 10^{-3} M $CuSO_4$ was 5.2 mg/kg dry wt of cells in 5 hrs, less than half that absorbed by cells pretreated with Cu or by cells pretreated with F, which indicates cause cannot be ascribed to differences in rate of Cu uptake. Author suggests that F blocks main respiratory pathway and Cu blocks the hexose monophosphate shunt.

1672. Haug, A., S. Melsom and S. Omang. 1974. Estimation of heavy metal pollution in two Norwegian fjord areas by analysis of the brown alga *Ascophyllum nodosum*. Environ. Poll. 7:179-192.

Concentrations, in mg/kg dry wt, in algae from Reine in Lofoten, a relatively unpolluted region, ranged from 60 to 110 for Zn, 4 to 8 for Cu, <3 for Pb, <0.7 for Cd, and 0.05 to 0.08 for Hg. Levels in mg/kg dry wt of algae from metals-impacted Trondheimsfjord ranged from 66-640 for Zn, 4 to 240 for Cu, <3 for Pb, <0.7 to 1.0 for Cd, and 0.05 to 0.18 for Hg. Cu and Zn contents increased with increasing age of vegetative tissue, but no pronounced seasonal variation was observed. Algae from the polluted Hardangerfjord contained, in mg/kg dry wt, 240 to 3700 of Zn, 3 to 160 of Cu, <3 to 95 of Pb, 0.7 to 16 of Cd, and 0.05 to 20 of Hg; Zn, Cd and Hg levels were elevated in algae collected 90 km from the main source, but Cu and Pb levels were normal 35 km from source. Authors suggest that analysis of seaweeds is a useful and inexpensive method for evaluating metal contamination.

1673. Haug, A. and O. Smidsrod. 1967. Strontium-calcium selectivity of alginates. Nature 215:757.

Using alginates of *Laminaria digitata* and *L. hyperborea*, the latter was found to be more efficient in reducing Sr uptake from the diet due to its larger content of guluronic acid residues.

1674. Healy, W.B., S. Cheng, and W.D. McElroy. 1955. Metal toxicity and iron deficiency effects on enzymes in Neurospora. Arch. Biochem. Biophys. 54:206-214.

Optimal growth rate for the fungi N. crassa occurred at 0.3 mg Fe/l; growth was reduced 50% by addition, in mg/l, of 200 Cu, 950 Mn, 3500 Mo, 500 Zn, 100 Co, or 150 Ni. Of these, only Co addition produced effects similar to Fe deficiency, as determined by activities of cytochrome oxidase, catalase, peroxidase, and succinic dehydrogenase enzyme systems known to contain Fe. Co toxicity and Fe deficiency also produced similar effects on the activities of nitrate reductase, "glucose 6-phosphate dehydrogenase," isocitrate dehydrogenase, DPNase, and alkaline phosphatase - enzyme systems not known to involve Fe. Increased Fe levels may partially offset the effects of Co toxicity on catalase and peroxidase. Authors suggest that Co competes with Fe.

1675. Heisinger, J.F. and W. Green. 1975. Mercuric chloride uptake by eggs of the ricefish and resulting teratogenic effects. Bull. Envir. Contamin. Toxicol. 14(6):665-673.

Zygotes collected from adult Oryzias latipes were incubated for 16 days in solutions containing 10, 15, 20, or 30 ug/l of Hg. Mean hatchability of controls was 46.7%. Experimentals incubated in 10 and 15 ug/l Hg had hatching percentages of 58.3 and 20.8, respectively; there was no hatch at 20 or 30 ug/l Hg. Hemorrhaging, blood vessel deterioration and loss of blood cells were observed in 79% of embryos in 15 ug/l; this was 100% at 20 and 30 ug/l. Neither controls nor those in 10 ug/l demonstrated any of these abnormalities. LC-100 (384 h) was between 20 and 30 ug/l; the LC-50 (16 days) value lies between 10 and 15 ug/l. Concentration factors for zygotes in 10, 15, 20, and 30 ug/l solutions were 1600, 19,000, 27,000, and 19,000 X, respectively; Hg residues after 16 days, in mg/kg, were 16, 29, 54, and 56, respectively.

1676. Held, E.E., V.A. Nelson, W.R. Schell and A.H. Seymour. 1973. Amchitka radiobiological program progress report. March 1972 to December 1972 (NVO-269-19). Univ. Washington, Coll. Fish., Lab. Radiat. Ecol., Seattle, Wash. 92 pp.

The present program was initiated in July 1970 at the request of the U.S. Atomic Energy Commission. It was designed to provide a periodic documentation of radionuclides, both naturally occurring and man-made, in biological and environmental samples from Amchitka and its environs (Aleutian chain). Seafoods and radionuclides potentially available to man through the food web were emphasized. However, organisms other than food organisms were also collected and analyzed in a search for indicator organisms (species that significantly concentrate one or more radionuclides). Concentrations of radionuclides other than those potentially hazardous to man were measured as a means of providing clues to the origin of radionuclides at Amchitka. Unexpected combinations or concentrations of radionuclides would indicate the presence of newly added radionuclides to the environment, presumably from fresh world fallout, nuclear-powered vessels, or from nuclear detonations at Amchitka Island.

The first progress report covered the period July 1970 to April 1971. It concluded that artificial or man-made radionuclides did not originate at Amchitka except for tritium which had previously been reported to be present in pond water and test holes near devices detonated in 1965 and 1969. A second progress report covered the period May 1971 to February 1972 and concluded that there was no release of radioactivity as a result of a third test. This report extends the account of the program through 1972. It includes analyses for: gamma-emitting radionuclides (K-40, Co-60, Zr-95, Nb-95, Ru-106, Sb-125, Cs-137) in air filters, seawater, freshwater, marine algae, marine invertebrates, marine fish, sea otter, and freshwater aufwuchs, moss, plants, and fish; strontium-90 in rats and birds; and tritium in seawater, freshwater and fish. Tables from the previous reports were revised recalculating values for zirconium-95 and niobium-95 and adding data for beryllium. The results of the recent analyses indicate that no new radionuclides are present. The most abundant radionuclides are naturally occurring Be-7 and potassium-40. Trace quantities of fission products, induced radionuclides and H-3 present are from world fallout, and a trace of H-3 contamination remains in some ponds as previously reported. It is concluded that there were no radionuclides of detonation origin in water, plants, and animals of Amchitka Island.

1677. Heneine, I.F., G. Gazzinelli and W.L. Tafuri. 1969. Iron metabolism in the snail Biomphalaria glabrata: Uptake, storage and transfer. Comp. Biochem. Physiol. 28:391-399.

After exposure to 0.02 mCi Fe-59/1 for 120 hrs, Fe-59 distributed in tissues of B. glabrata as follows: 45% hepatopancreas, 13% ovotestis, 4% mantle, 2% albumen gland, 4% digestive gland, 0.4% male genitalia, 0.7% female genitalia, 9% kidney, 0.4% central nervous system, and 22% in cephalopodal mass. Fe-59 was taken up directly by hepatopancreas and transferred to ovotestis. Ferritin, hemosiderin or both were present in hepatopancreas and ovotestis. It was concluded that hepatopancreas is an active metabolic storage depot for Fe.

1678. Heslinga, G.A. 1976. Effects of copper on the coral-reef echinoid Echinometra mathaei. Marine Biology 35:155-160.

Effects of copper-enriched seawater on fertilization success, early cleavage, larval skeletal development, and survival of adult E. mathaei were tested. Fifty percent reduction of fertilization success occurred at 0.18 mg Cu/l; for 50% cleavage success to the 8-cell stage this was 0.42 mg Cu/l. Adults had respective 48- and 96-hr LC-50 values of 0.54 and 0.30 mg/l. Larval skeletal development was suppressed in 0.02 mg/l. The latter process appears to be very sensitive and may be most suitable for assessing effects of stress on this species.

1679. Hessler, A. 1974. The effects of lead on algae. I. Effects of Pb on viability and motility of Platymonas subcordiformis (Chlorophyta: Volvocales). Water, Air, and Soil Poll. 3:371-385.

Effects of lethal and sublethal concentrations of $PbCl_2$ on reproduction, viability, and motility of a marine unicellular green flagellate alga were studied under controlled laboratory conditions. Severity of effects depended primarily upon Pb concentration and duration of treatment. Log phase cells were more sensitive than stationary phase cells. Sublethal amounts of Pb (2.5 and 10 mg/l Pb) tended to retard population growth by delaying cell division and daughter cell separation; higher levels (60 mg/l Pb) caused growth inhibition and death. Various intracellular abnormalities resulted from Pb treatment: flagella were shed or altered in a variety of ways, depending on Pb concentration; motility was least affected by low Pb and completely impaired by high Pb; normal wild-type cells appeared to be more sensitive to Pb than mechanically sheared (flagella-less) cells, and cells of a non-flagellate mutant of Platymonas. Exposure of cells to Pb in non-growth conditions of dark and cold (2 C) had little negative effect.

1680. Hessler, A. 1975. The effects of lead on algae. II. Mutagenesis experiments on Platymonas subcordiformis (Chlorophyta: Volvocales). Mutation Res. 31:43-47.

Under conditions in which two known mutagenic agents, ultraviolet irradiation and nitrosoguanidine, induced high proportions of mutations, chiefly those affecting growth rate and colony form, it was observed that sublethal concentrations of $PbCl_2$ ranging from 100 to 500 mg/l of Pb, and a lethal concentration of 1000 mg/lg Pb^2, produced no appreciable increase in incidence of such mutant types above the spontaneous frequency in Platymonas subcordiformis.

1681. Heyraud, M. and S.W. Fowler. 1973. Comparative studies on the bioretention of radionuclides under laboratory and field conditions. Thalassia Jugoslavica 9:127-137.

For clam *Tapes decussatus*, polychaete *Hermione hystrix*, and crab *Pachygrapsus marmoratus*, there were no significant differences in Zn-65 loss rate within each organism when held in seawater collected *in situ* or in seawater from the laboratory system. Addition of 100 µg Zn/l to the medium accelerated Zn-65 flux rates. Simultaneous laboratory and field experiments indicated that Zn-65 loss rates in clam and mussel *Mytilus galloprovincialis*, were similar whether animals were held in field or laboratory. Mussels labelled for 75 days lost Zn-65 more slowly than those labelled for 11 days. During the summer, crabs lost Zn-65 significantly faster in the laboratory than in the field. But during winter, when water temperatures were lower, no differences in loss rates between systems were observed. Seasonal differences may be due to variations in molt cycle. Authors concluded that care should be taken when comparing lab and field results for the same species.

1682. Heyraud, M., S.W. Fowler, T.M. Beasley and R.D. Cherry. 1976. Polonium-210 in euphausiids: A detailed study. Marine Biology 34:127-136.

Polonium-210 concentration in *Meganyctiphanes norvegica* decreases from 1.1 pCi/g dry material to 0.4 pCi/g dry material as the mean dry wt increases from 19 to 76 mg. This higher concentration in smaller specimens cannot be explained on basis of surface absorption but is probably related to food ingestion. Muscular mass, eyes and exoskeleton of euphausiids all contain 1 pCi/g dry wt or less, whereas alimentary tract has 9.9 pCi/g and hepatopancreas 23.6 pCi/g. A model was formulated to determine flux of Po-210 through *M. norvegica*. Calculations confirmed that food is the main source of Po-210 and fecal pellets constitute the major elimination route. Extrapolation of data to zooplankton leads to the conclusion that zooplankton metabolic activity is important in transport of Po-210 from surface to oceanic depths.

1683. Hidaka, I. 1970. The effects of transition metals on the palatal chemoreceptors of the carp. Japanese Jour. Physiol. 20:599-609.

Electrical responses of the palatine nerve innervating the palatal organ of *Cyprinus carpio* when stimulated by sucrose, were depressed by external application of low concentrations of Na_2PtCl_6, $NaAuBr_4$, $NaAuCl_4$, $HgCl_2$, and $TlCl_3$. Response to NaCl was not affected or occasionally enhanced. $CuSO_4$, $ZnSO_4$, $AgNO_3$, and $UO_2(CH_3COO)_2$

depressed both sucrose and NaCl responses. Depression of sugar receptor increased with rising $NaAuCl_4$ concentration and was recovered by cysteine. It appears that reaction of receptor with chloraurate occurs at the receptor membrane. N-ethylmaleimide and iodoacetate depressed sucrose and NaCl responses non-selectively. Histidine could recover gold depression of sugar receptor, though more weakly than cysteine. It was concluded that some reactive groups other than sulfhydrils were responsible for receptor membrane reaction with gold ions, but -SH groups were responsible for other metals effects.

1684. Hiltibran, R.C. 1971. Effects of cadmium, zinc, manganese, and calcium on oxygen and phosphate metabolism of bluegill liver mitochondria. Jour. Wat. Poll. Contr. Fed. 43:818-823.

Cadmium and zinc, at levels of 0.37 mg/l and 2.14 mg/l, respectively, were found to alter oxygen metabolism. Both oxygen and phosphate metabolism were altered by calcium (levels of 6.8 and 13.2 mg/l, respectively) and manganese (93.5 mg/l for both). Results indicate that Cd and Zn can disrupt energy production by inhibition of oxygen uptake within cell, and that this disruption can occur at relatively low levels and be of such severity as to cause death of fish, particularly bluegill.

1685. Hiltner, R.S. and H.J. Wichmann. 1919. Zinc in oysters. Jour. Biol. Chem. 38:205-221.

Zinc is present universally in oysters, at least in those grown in Atlantic waters. There is no direct relation between Zn content and body wt of oysters, nor uniformity of ratio of Zn to Cu, nor correlation between Zn content of oysters and water in which they grew. Vegetation and organic matter dredged up with oysters in the locality studied contained notable quantities of Zn and in some instances traces of Cu. As in *Sycotypus*, a predatory snail, Zn is probably always associated with Cu. It seems probable that Zn, as well as Cu, can be absorbed and retained in tissues of oysters in quantities far in excess of functional requirements, especially in oysters grown in waters badly polluted with metallurgical and factory wastes. Concentrations of Zn in oysters, in mg/kg wet wt, was determined for a variety of locations by several investigators and ranged between 26 and 2298; for Cu this was 6 to 539; for arsenic, none to 1.47.

1686. Hochberg, M.L. and M.L. Sargent. 1973. Regulation of repressible alkaline phosphatase by organic acids and metal ions in *Neurospora crassa*. Canadian Jour. Microbiol. 19:1487-1492.

Various organic acids used in standing cultures of Neurospora regulate specific activity of mycelial repressible alkaline phosphatase. Regulatory control occurs primarily through chelation of metal ions which are necessary for the production or stability of the enzyme. Both Fe^{2+} and Zn^{2+} were needed in growth medium for maximum enzyme level, while a high Cu^{2+} concentration depressed enzyme level. Concentrations of 2.55 M Fe^{2+}, 1.75×10^{-5}M Zn^{2+} and 1.75×10^{-4}M Zn^{2+} added to a citrate medium increased mycelial enzyme activities 25%, 63%, and 73%, respectively. Electrophoresis of mycelial extracts on gradient polyacrylamide gels demonstrated that the organic acids and Fe^{2+} do not have these regulatory effects on repressible or constitutive acid phosphatases of Neurospora.

1687. Hodgkin, A.L. and B. Katz. 1949. The effect of sodium ions on the electrical activity of the giant axon of the squid. Jour. Physiol. 108:37-77.

Measurements made using a microelectrode in squid giant axons showed that in absence of Na, action potential is abolished, but will return to normal when seawater is applied. Dilution of seawater will slightly increase resting potential, but produce a large and reversible decrease in height of action potential, with reversed potential difference going to zero when Na concentration is <30% normal. Hypertonic solutions of NaCl produce an increase of action potential but have no effect on resting potential. The rate of rise (up to 140%) or decline (to 10%) of action potential is directly proportional to external Na concentration. Conduction velocity undergoes substantial decrease in solutions of low Na content. Changes produced by dilution of seawater with isotonic dextrose appear to be caused by reduction of the Na concentration and not by alterations in concentrations of other ions. Removal or addition of external K produces an increase or decrease, respectively, in both action and resting potentials. It was concluded that permeability conditions of membrane in active state are reverse of those in resting state, with resting membrane more permeable to K than Na, and active membrane more permeable to Na than K. The reverse is thought to be caused by variations in Na permeability only, with a reversed membrane potential occurring when external Na is greater than Na in axoplasm.

1688. Hodson, P.V. 1975. Zinc uptake by Atlantic salmon (Salmo salar) exposed to a lethal concentration of zinc at 3, 11, and 19 C. Jour. Fish. Res. Bd. Canada 32:2552-2556.

Salmon acclimated to 3, 11, and 19 C accumulated high concentrations of zinc in gill tissues during exposure to 14 mg Zn/l for 8 hrs. Using Zn-65 as a tracer, rate of Zn uptake increased from a minimum at

3 C to a maximum at 19 C. Among fish dying during exposure, Zn concentrations in gill were highest at 19 C and lowest at 3 and 11 C.

1689. Hodson, P.V. 1976. Temperature effects on lactate-glycogen metabolism in zinc-intoxicated rainbow trout (Salmo gairdneri). Jour. Fish. Res. Bd. Canada 33:1393-1397.

Lactate production and glycogen utilization in dorsal white muscle of rainbow trout increased during exposure for 18 hrs to 14-15 mg of Zn/1. Exposure at 3, 11 and 19 C did not affect timing or percent change of lactic acid production or utilization of glycogen. It was concluded that previously observed high tolerance of Zn by warm-acclimated fish is not due to increased resistance to tissue hypoxia caused by gill damage.

1690. Hodson, P.V. and J.B. Sprague. 1975. Temperature-induced changes in acute toxicity of zinc to Atlantic salmon (Salmo salar). Jour. Fish. Res. Bd. Canada 32:1-10.

Three groups of salmon were acclimated to water temperatures of 3, 11, and 19 C, and exposed to zinc concentrations of 1 to 30 mg/1. Cold-acclimated salmon (3 C) survived longer (300 h) but were less tolerant (LC-50 = 3.5 mg/1 Zn) than warm-acclimated (19 C) salmon (LC-50 [22 hr] = 5 mg/1). Moderate (8 C) and severe (16 C) heat stresses shortened time to mortality and either increased (8 C) or caused no change (16 C) in tolerance. Moderate and severe cold stresses lengthened time to mortality similarly, but decreased tolerance. When acclimated, rate of mortality was a function of temperature; a 10 C increase in acclimation temperature caused a 3.1-3.3 X increase in mortality. When exposure temperature (Te) does not equal acclimation temperature (Ta), LC-50 may be predicted by the equation LC-50 = 1.9611-0.1873 Ta + 0.8699 Te - 0.0414 Te^2 + 0.00004 Ta Te^3. Using this model and field measurements, authors predicted that extensive mortality may occur among salmon in the Miramichi River, New Brunswick in winter when copper and zinc pollution exceeds 4.0 toxic units (threshold lethality = 1.0 toxic units).

1691. Hoese, H.D. 1960. Biotic changes in a bay associated with the end of a drought. Limnol. Oceanogr. 5:326-336.

When Mesquite Bay, Texas underwent a salinity drop of 30^{o}/oo due to heavy river discharge, complete mortality of stenohaline marine sessile and infaunal molluscs occurred. Mortality of euryhaline molluscs occurred when salinities fell below 3^{o}/oo. A high salinity Ostrea equestris-Brachidontes exustus community was replaced by a Crassostrea virginica-Brachidontes recurvus community. Rapid lowering of salinity apparently did not kill fishes and other motile forms. It was concluded that these species must have emigrated, although several stenohaline species were found in very low salinities immediately after influx of fresh water.

1692. Holden, A.V. 1973. Mercury in fish and shellfish. A review. Jour. Fd. Technol. 8:1-25.

A review of the mercury problem is given beginning with Hg measurements in salt water fish of 0.04 to 0.15 mg/kg in the 1930's. Recent values for over 16 species of freshwater fish from 7 different countries ranged from 0.01 to 11.2 mg/kg fresh tissue. In marine regions concentration factors of 1000-2500 for organic Hg and 1-50 for inorganic Hg, taken up directly from seawater, were measured. Compiled from various studies, the following ranges in Hg concentrations, in mg/kg wet wt, are given: plaice 0.031-3.10; flounder <.01-2.5; herring 0.013-1.39; menhaden 0.34; anchovy 0.44; cod 0.013-2.70; tuna 0.032-1.0; swordfish 0.82-1.00; lobster 0.08-0.75; crab 0.06-0.15; oyster 0.02-0.20; mussel 0.02-0.65; clams 0.02-0.11; adult harp seals 0.34 (meat) and 5.12 (liver); gray seal 1.13 (muscle) and 99 (liver); freshwater ringed seal 197 (flesh) and 210 (liver); Atlantic finwhale 0.06; humpback whale 0.24; and Beluga whale 0.97 (meat) and 8.87 (liver). Also given are various lethal dose studies and methods used to determine Hg.

Effects of Hg on man, including the Minimata incident, are discussed. Man's impact on equilibrium level of Hg in the oceans, its long term effects and biological magnification of Hg along food chain are considered in determining a safe and practical maximum Hg level for consumption. Author concludes that a maximum residue level of 1 mg/kg would be well within acceptable limits for man and cause little difficulty to fisheries (except for some areas where freshwater fish are involved). If the maximum were reduced to 0.5 mg/kg or less, serious problems could arise with certain species, particularly tuna and swordfish.

1693. Holden, A.V. 1973. Mercury and organochlorine residue analysis of fish and aquatic mammals. Pestic. Sci. 4:399-408.

Methods for methylmercury and total mercury analysis have been found suitable for the majority of types of fish tissue and for dried fish meal, but those of high lipid content occasionally present difficulties. Lipids which have not been completely digested in the first stage of analysis for total mercury may lead to interference. A number of organic and inorganic substances, such as iodides, ozone, sulphides, acetone and cyclic compounds interfere at the same wavelength as mercury.

Nevertheless, reproducibility of the total mercury method described is good, the standard deviation found for most fish tissue being ±4 to 8%. Methylmercury is the most toxic form of the element and therefore of interest in the analysis of fish, but the technique described is less reproducible, and slower, than that for total mercury. Because the proportion in the methyl-form is at least 80% in fish and commonly about 95%, the total mercury technique is the method of choice for monitoring residues in fish.

Of the organochlorine pesticides, the only residues now commonly found in freshwater and marine fish, sometimes in concentrations up to at least 0.1 mg/kg, are dieldrin, pp'-DDT, and its two metabolites TDE and DDE, although hexachlorobenzene, alpha- and gamma-BHC may sometimes be detected. Marine fish also contain significant amounts of PCBs, often up to 1 mg/kg in some organs and it seems likely that freshwater fish in heavily polluted areas will also contain PCBs.

1694. Holden, A.V. 1975. The accumulation of oceanic contaminants in marine mammals. Rapp. P. -v. Réun. Const. int. Explor. Mer 169:353-361.

Grey seals Halichoerus grypus, and common seals Phoca vitulina, from the west, north and east coasts of Great Britain, which were also analyzed for pesticide residues and PCBs, contained greatest concentrations of Hg in liver. Mean concentration of Hg in seal liver, in mg/kg wet wt, was 1.6 in seals 84-114 cm in length, 96 in seals 117-152 cm and 178 in those 155-254 cm. Mercury concentration for the three respective size classes were 0.14, 0.29 and 0.34 mg/kg wet wt in brain, and 0.03, 0.06, 0.05 mg/kg in blubber. Mean zinc levels in seals, in mg/kg wet wt, were: liver 54; muscle 34; heart 31; kidney 37; spleen 32; brain 26; and blubber 9. Average seal liver concentrations, in mg/kg wet wt, were 14 for Cu, 8 for Pb and 1.2 for Cd.

1695. Holden, A.V. and G. Topping. 1972. XIV - Occurrence of specific pollutants in fish in the Forth and Tay Estuaries. Proc. Roy Soc. Edin. B. 71(14):189-194.

Mean mercury contents of lobster Homarus vulgaris, from various locations on the Scottish coast ranged from 0.21 to 0.54 mg/kg wet muscle. Metal levels of 7 species of Scottish fish in mg/kg wet muscle, ranged from 0.06 to 0.16 for Cd, <0.5 to 1.0 for Pb, 0.32 to 1.6 for Cu, and 1.7 to 14.7 for Zn. Organochlorine residues were also examined.

1696. Hollifield, K.L. and R.V. Dimock, Jr. 1974. Interaction of temperature and salinity on crab metabolism. Amer. Zool. 14:1259.

Metabolism was measured for Panopeus herbstii acclimated to 10 C and 30°/oo, 10 C and 5°/oo, 23 C and 30°/oo, and 23 C and 5°/oo. Measurements were made at experimental salinities of 40, 30, 15, and 5°/oo at both 25 C and 10 C. Significant interaction between temperature and salinity occurred. For animals acclimated to 23 C and 30°/oo, highest metabolic rates occurred at low experimental salinity at 25 C test temperature. The same animals tested at 10 C had highest metabolism at high salinity. After low temperature acclimation, metabolism was higher at low salinity under all experimental conditions. Temperature acclimation had the most consistent effect on metabolism at low acclimation salinity and high test temperature. Q_{10} varied with salinity. Sexual differences occurred only in animals acclimated to 23 C and 5°/oo and tested at 25 C. Females exhibited significantly lower metabolic rates than males under these conditions.

1697. Holmes, A.D. and R. Remington. 1934. Arsenic content of American cod liver oil. Ind. Eng. Chem. 26:573-574.

Twenty samples of crude, medicinal, American cod liver oils were examined for arsenic. The samples represented typical oils from the various American centers producing cod liver oil. Arsenic content varied from 1.4 to 5.1 mg/kg with an average of 2.6 ± 0.13. These values are materially higher than common fruits and vegetables, about the same as American marine fish and shellfish, and decidedly lower than crustaceans. Data were not available concerning the nutritional or therapeutic value of arsenic by regular consumption of cod liver oil, although it is believed to be present in a form of low or no toxicity.

1698. Hoover, W.L., J.R. Melton, P.A. Howard and J.W. Bassett, Jr. 1974. Atomic absorption spectrometric determination of arsenic. Jour. AOAC 57(1):18-21.

Two methods for As determination with sensitivities of 0.5 and 0.1 mg As/kg wet wt are described. Applied techniques yielded values of 3.0 to 6.8 mg As/kg for fish muscle, and 6.1 to 6.4 for crab muscle.

1699. Hopkins, R. and J.M. Kain. 1971. The effect of marine pollutants on Laminarea hyperboria. Marine Poll. Bull. 2:75-77.

Two different techniques were used to determine toxic concentrations of mercury copper, zinc, herbicides, detergents and insecticides, to L. hyperborea. Culture experiments lasting 28 days in which zoospores developed into gametophytes then sporophytes under given concentrations of pollutants was one technique. Another used a respirometer, where the pollutant was added at 90 minutes and followed for 26 hours in the dark. In culture experiments, the toxic concentration was the lowest one tested in which plant growth differed from the control. For Hg, Cu and Zn, these were 0.01, 0.05 and 0.25 mg/l, respectively. In the respirometer approach the lethal concentrations were determined as those which inhibit respiration; for Hg, Cu, and Zn, these concentrations were 10, 100, and 1000 mg/l, respectively.

1700. House, C.R. 1963. Osmotic regulation in the brackish water teleost, *Blennius pholis*. Jour. Exp. Biol. 40:87-104.

In full strength seawater this species was calculated to drink 0.62 g Na/kg fish/hr. Total flux of Na in *B. pholis* in 100% SW was 2.3 g/l blood/hr; in both 40 and 10% SW this was 0.46. On the basis of this and other studies it was concluded that there is active outward excretion of chloride ions in animals adapted to 150, 100 and 40% SW, and active inward absorption of chloride ions in 10% SW and Na ions in animals adapted to 40 and 10% SW.

1701. Huckabee, J.W., C. Feldman, and Y. Talmi. 1974. Mercury concentrations in fish from the Great Smoky Mountains National Park. Anal. Chim. Acta. 70:41-47.

Mean Hg concentrations of fish from 3 high altitude streams in the Great Smoky Mountains, 20-25 km from nearest pollution source, in mg/kg, were: rainbow trout *Salmo gairdneri* 0.036; brook trout *Salvelinus fontinalis*, 0.018; banded sculpin *Cottus carolinae* 0.025; rosyside dace *Clinostomus funduloides* 0.044; and stoneroller *Campostoma anomalum* 0.039. There was no significant difference in Hg concentration among fish analyzed whole, with gastrointestinal tract removed, or a strip of axial musculature. There was a significant (p = >0.05) difference in Hg concentration among species in one stream and in 3 species from different streams. Methyl-Hg constituted 93 ± 2.6% of the total Hg. Results indicate that all fish acquire the same tissue concentrations of Hg at chronic low level exposure.

1702. Huckabee, J.W. and N.A. Griffith. 1974. Toxicity of mercury and selenium to the eggs of carp (*Cyprinus carpio*). Trans. Amer. Fish. Soc. 103(4):822-825.

Carp eggs were exposed to trace amounts of Hg and Se to test for effect on hatchability. Test concentrations of Hg, as $HgCl_2$, and SeO_3^{2-} as SeO_2, were 1, 2, 3, 4, and 5 mg/l each, and each possible combination of these concentrations. No eggs hatched when incubated in ≥ 4 mg/l Hg, but up to 5 mg/l SeO_3^{2-} had no effect on hatchability. Three mg/l was the lowest concentration of Hg that had an effect on hatchability. When 1 mg/l concentrations were tested, the percent hatch dropped from >99% to <20% when the elements were alone and combined, respectively.

1703. Hueck, H.J. and D.M.M. Adema. 1968. Toxicological investigations in an artificial ecosystem. A progress report on copper toxicity towards algae and daphniae. Helgolander wiss. Meeresunters. 17:188-199.

Bioassay apparatus is described using algae, microcrustaceans and fishes to simulate a food chain. Preliminary results with copper, Chlorella pyrenoidosa, and Daphnia magna in an algae-crustacean two-stage experiment are given. Continuous flow tests were more sensitive to D. magna than static tests. Reproduction was the most sensitive parameter measured with a concentration of 56 ug/l of Cu shown limiting for development of D. magna. At a concentration of 1000 ug/l, development is limited in C. pyrenoidosa; accumulation factors for Cu are about 4000 to 5000 X. When fed with algae cultured in copper-containing media, D. magna growth is inhibited at 560 ug/l Cu in the algal medium. D. magna is therefore more sensitive to dissolved Cu than to Cu in food. Taking into account rate of feeding, provisional calculations suggest that actual amount of Cu available to daphnids is higher via food than direct absorption from medium.

1704. Huggett, R.J., F.A. Cross and M.E. Bender. 1975. Distribution of copper and zinc in oysters and sediments from three coastal-plain estuaries. In Howell, F.G., J.B. Gentry and M.H. Smith (eds.). Mineral Cycling in Southeastern Ecosystems. U.S. Energy Res. Dev. Admin.: 224-238. Available as CONF-740513 from NTIS, U.S. Dept. Comm., Springfield, VA 22161.

Oysters from the Newport River estuary, North Carolina, contained 125 to 325 mg Zn/kg wet wt of soft parts and 2.2 to 6.2 mg Cu/kg. For the Rappahannock River estuary, Virginia, oysters contained 275 to 425 mg Zn/kg wet wt and 3 to 29 for Cu. In all cases, higher metal concentrations occurred in animals living in lower-salinity waters. Concentration levels in oysters were not directly related to concentrations in sediments.

1705. Huggins, A.K., D. Amrit, and C. Haworth. 1975. Biochemical changes in crustaceans and other species associated with alterations in environmental salinity. Biochem. Soc. Trans. 3:669-671.

Using C-14 tracer, amount of various amino acids oxidized at two salinities (850 and 340 mosmolal) in whole crab, *Carcinus maenas*, was calculated. At the higher salinity, glutamate, glycine, and proline had similar oxidation rates (0.020, 0.021, and 0.018 umol/h per g wet wt, respectively). At the lower salinity, contribution of glycine C to CO_2 produced increased nearly 5 X, to an oxidation rate of 0.099, while glutamate and proline increased to only 0.037 and 0.035, respectively. Thus glycine supplies additional oxidizable C during adaptation to a decreased environmental salinity. Preliminary data with the crabs *Maia* and *Portunas* suggests a similar mechanism, but this was not observed for the euryhaline teleost *Agonus cataphractus*.

1706. Hunter, W.R. 1949. The poisoning of *Marinogammarus marinus* by cupric sulphate and mercuric chloride. Jour. Exp. Biol. 26:113-124.

Using behavioral criteria, mercury affected the marine amphipod *M. marinus* at levels of 2.5 mg/l in seawater, and 0.5 mg/l in distilled water. In artificial seawater, copper had no effect at levels <50 mg/l. Toxicities of Cu and Hg at concentrations of 5 mg/l were increased by decreasing salinity. Cu levels from 0.2 to 2.5 mg/l increased Hg toxicities, but 0.4 to 0.75 mg Hg/l did not effect Cu toxicities. In both artificial seawater and distilled water, oxygen consumption was depressed by 25 mg Cu/l but not by 50 mg Cu/l.

1707. Hutcheson, M.S. 1974. The effect of temperature and salinity on cadmium uptake by the blue crab, *Callinectes sapidus*. Chesapeake Science 15:237-241.

Adult crabs were exposed to various concentrations of cadmium in seawater at different thermosaline regimes. Gill and hepatopancreas were major sites of cadmium accumulation. Gill showed steady linear increase of Cd with time; at 20 C, uptake increased with decreasing salinity; at 5^{o}/oo S, uptake increased with increasing temperature. Highest concentration factors in gill were 6-8 times that of 10 mg/l Cd^{2+} in water after 96 hours under regimes of 20 C, 20^{o}/oo; 20 C, 30^{o}/oo; and 10 C, 5^{o}/oo. Mean Cd values (in mg/kg) after 96 hr in respective regimes were approximately: 76, 55, and 70. Hepatopancreas also accumulates Cd in linear fashion; at 5^{o}/oo S uptake rate increases with increasing temperature. Maximum Cd levels at 20 C, 20^{o}/oo was much higher after 96 hrs in hepatopancreas than gills (175 mg/kg Cd *vs* 79). When crabs were removed from 10 mg/l Cd^{2+} water and placed in Cd-free seawater, no loss of metal accumulation occurred within 96 hrs. After 27 days of exposure to 0.2 mg/l Cd^{2+} at 20 C - 30^{o}/oo, Cd concentrations (in mg/kg) were 3.4 in carapace, 54 in gills and 20 in hepatopancreas.

Crabs died in T-S regimes of 20 C, 20^{o}/oo (after 96 hrs), 20 C, 5^{o}/oo (after 72 hrs), and 33 C, 5^{o}/oo (after 24 hrs). Concentrations of cadmium in gills of live crabs at these times were 79, 83, and 79 mg/kg Cd, respectively. This suggests a threshold level of approximately 80 mg/kg cadmium in gill. At low concentrations of Cd^{2+} in water (0.11 mg/l for 8 days and 0.2 mg/l for 27 days), no cadmium accumulated in claw muscle.

1708. Hutchinson, G.E. 1932. Experimental studies in ecologie. I. The magnesium tolerance of *Daphniidae* and its ecological significance. Int. Revue Ges. Hydrobiol. u. Hydrograph. 28:90-108.

Magnesium tolerance levels, defined as Mg concentrations in mg/l which prevent successful reproduction were: 0.24 for *Daphnia magna*, 0.03 for *D. thomsoni*, 0.12 for *D. pulex*, 0.03 to 0.06 for *D. longispina*, 0.06 for *Ceriodaphnia reticulata*, and 0.18 for *Moina macrocopa*. For *D. pulex*, *D. magna* and *C. reticulata*, LC-100 (5 day) values for Zn were <0.65 g/l. The implications of these findings to account for absence of cladocerans in Lake Tanganyika is discussed.

1709. Hutchinson, T.C., A. Fedorenko, J. Fitchko, A. Kuja, J. Vanloon and J. Lichwa. 1976. Movement and compartmentation of nickel and copper in an aquatic ecosystem. *In* Nriagu, J.O. (ed.). Environmental Biogeochemistry, Vol. 2, Metals Transfer and Ecological Mass Balances. Ann Arbor Sci. Publ., Ann Arbor, Mich.: 565-585.

Nickel, copper and zinc were determined in water, sediments, macrophytic vegetation, algal periphyton, crustaceans, molluscs, and fish taken from rivers and reservoirs of the Sudbury, Ontario area, an area where mining and smelting activities proliferate. Approximate concentration factors for different ecosystem components for Ni, Cu and Zn were: sediment, Ni 5300, Cu 12,000, and Zn 9700; algal periphyton, Ni 19,600, Cu 17,600, and zinc 15,000; macrophytic vegetation (*Potomageton* sp.), Ni 11,400, Cu 9000, and Zn 6500; zooplankton, Ni 643, Cu 3400, and Zn 15,700; clams, Ni 262, Cu 2,200, and Zn 21,500; benthos (crayfish), Ni 929, Cu 39,100, and Zn 24,000; omnivorous fish (brown bullhead), Ni 226, and Cu 149; and for carnivorous fish (yellow pickerel), Ni 329 and Cu 156.

Metal concentrations in sediments reflected inputs from industrial activity. Levels of Ni and Cu in water varied according to input source and correlated well with levels in periphyton, zooplankton and minnows, suggesting uptake. Metal concentrations of sediments correlated significantly with concentrations in rooted macrophytes. Aquatic fauna showed selectivity in metal uptake with Ni excluded relative to Cu and Zn in clams and crayfish. Fish had lowest metal levels implying that while very large concentration factors exist for many parts of the ecosystem, food chain biomagnification apparently does not occur.

1710. Hyvarinen, H. and T. Valtonen. 1973. Seasonal changes in the liver mineral content of *Coregonus nasus* (Pallas), *sensu* Svardson, in the Bay of Bothnia. Comp. Biochem. Physiol. 45B:875-881.

Copper content of adult whitefish liver was lowest during summer and autumn in both sexes, but increased markedly during the winter (mean 16 mg Cu/kg fresh wt). Zinc content appeared to be independent of season or sex (highest average value = 38 mg Zn/kg). For magnesium, levels were highest in summer and lowest in winter; males exhibited significantly lower zinc values than females; a similar pattern was observed for calcium. Authors concluded that changes in liver mineral content are associated with metal constituents of the metal enzyme complexes or with changes in metalloenzyme concentrations.

1711. Ichikawa, R. 1960. Strontium-calcium discrimination in the rainbow trout. Rec. Oceanogr. Works Japan 5(2):120-131.

In lake water, trout uptake ratio of Sr:Ca in muscle and bone was 0.4 that of environmental levels. However, at levels of 1 to 12 mg Sr/l (Sr:Ca ratios of 0.04 to 1.0), uptake ratios were 0.2 that of medium. From dietary uptake, the Sr:Ca ratio was 0.7 that of food.

1712. Ikuta, K. 1968. Studies on accumulation of heavy metals in aquatic organisms - II. On accumulation of copper and zinc in oysters. Bull. Jap. Soc. Sci. Fish. 34(2):112-116. (In Japanese, English summary)

Oysters were transplanted from Urashiro Bay, a control region with water concentrations of 0.5-2.3 μg Cu/l and 5.7-37 μg Zn/l, to Akimizu Inlet with 1.0-6.4 μg Cu/l and 8-42 μg Zn/l. After 120 days oysters contained 190 mg/kg wet wt Cu and 580 mg/kg wet wt Zn. Controls in Urashiro Bay had metal levels, in mg/kg, of 25 for Cu and 200 for Zn. Cu content in transplanted oysters increased exponentially, whereas Zn increased in sigmoidally.

1713. Ikuta, K. 1968. Studies on accumulation of heavy metals in aquatic organisms. III. On accumulation of copper and zinc in the parts of oysters. Bull. Jap. Soc. Sci. Fish. 34(2): 117-122. (In Japanese, English abstract)

Zinc and copper in mantle, gill, labial palp, adductor muscle and remainder were determined for clean oysters transplanted for 120 days to an area where green oysters occur. Levels of copper increased exponentially in some cases, reaching 65 mg Cu/kg wet wt in adductor muscle, 205 in mantle, 255 in gill, 1237 in labial palp, and 100 mg Cu/kg in remainder. Exponential accumulation of zinc occurred in some instances, reaching 250 mg/kg in adductor muscles, 800-900 in labial palp, mantle, and gill, and 300 in remainder. In other instances zinc did not follow any distinct pattern. Ratios of metal concentrations in parts of oysters to levels in whole bodies for mantle, gill, and labial palp were >1, but for adductor muscle and remainder, <1.

1714. Ikuta, K. 1968. Studies on accumulation of heavy metals in aquatic organisms. IV. On disappearance of abnormally accumulated copper and zinc in oysters. Bull. Jap. Soc. Sci. Fish. 34(6):482-487.

Oysters *Ostrea gigas*, with abnormally accumulated Cu and Zn were transplanted into clean water to determine depuration rate. During the 116 day study, Cu, in mg/kg wet wt, decreased in mantle from 286 to 14, in gill from 430 to 15, in labial palp from 264 to 18, in adductor muscle from 58 to 5, in remainder from 214 to 13, and in whole body from 232 to 12. During the same period zinc decreased in mantle from 1072 to 95, in gill from 1270 to 171, in labial palp from 2178 to 112, in adductor muscle from 221 to 37, in remainder from 1013 to 122, and in whole body from 953 to 108. Accumulated Cu did not depurate until at least 2 weeks post-transplantation. Zinc, however, began to depurate immediately. Copper depuration rate is 2X that of zinc. Contents of these metals and ratio of zinc to copper were normal when individuals had grown 4X in weight (116 days).

1715. Ikuta, K. 1972. Studies on green oyster. Bull. Fac. Agric., Miyazaki Univ. 19(1):116 pp. (In Japanese, English Abstract)

Through laboratory experimentation, the following formula was derived to describe copper accumulation in oysters:
$\log y = at\frac{\log Y-a'}{b'}$ $(t \geq 1)$, where y is the copper accumulation quantity, Y is copper concentration in seawater, a is initial level of copper content, t is days of immersion, and a' and b' are constants of the standardizing line, and dependent on water temperature. Copper accumulation is proportional to temperature with calculated values of copper being: 5.21 ug Cu/l at 15 C, 1.71 ug Cu/l at 20 C, and 0.44 ug Cu/l at 25 C in

individual oysters. Accumulation also differs with salinities of coastal and oceanic water, being greater in coastal waters having the same copper concentrations as oceanic waters. Interaction of copper with other metals under certain concentrations is recognized. It is suggested that 5 ug Cu/l should be adopted as the new water quality criterion (presently set at 7.5 ug Cu/l), for at this level (including both ionic copper and copper in food substances) green discoloration does not occur over long time periods. The process of copper accumulation by oysters involves absorption onto mucous sheets, transport across cell membrane to acidophilic granules in epithelial cells for storage, and excretion of copper. This process is probably common to other heavy metals with positive polyvalent ions. All information obtained appears to represent a common relationship between other genera of bivalves and heavy metals.

1716. Imai, T. and M. Sakanoue. 1973. Content of plutonium, thorium and protactinium in seawater and recent coral in the North Pacific. Jour. Ocean. Soc. Japan 29:76-82.

Pu-239 content of North Pacific, East China Sea, and Japan Sea surface waters ranged from 0.6 to 1.6 pCi/1000 l, with Pu-238/Pu-239 activities ratios of 0.2 to 0.7. Thorium-228/Thorium-232 activity ratios for North Pacific waters varied between 7.6 and 30, whereas the East China Sea ratio was 65. Contents of protactinium-231 are <6% of that in equilibrium with its parent U-235. Plutonium isotopes have concentrated in recent coral from Yoron Island with concentration factors of 1×10^3 to 2×10^3.

1717. Imanishi, N. 1959. Studies on the inorganic chemical constituents of sea fishes. Records. Oceanog. Works Japan 3:135-139.

Cu, Pb, Sn, Fe, Al, Mn, Zn, Ca, Mg, Na, K, and Si were determined spectrographically in ash samples from 8 species of deep water fish caught at 200-300 m in the Bay of Tosa, Kochi prefecture, Japan.

1718. Ingram, L.O. and E.L. Thurston. 1976. Potassium requirement for cell division in Anacystis nidulans. Jour. Bact. 125(1):369-371.

A. nidulans, an autotrophic blue-green bacterium, has a K requirement of 0.7% of cellular dry wt. K starvation partially dissociates growth from division, inducing 50% of population to form filaments.

1719. Ireland, M.P. 1973. Result of fluvial zinc pollution on the zinc content of littoral and sublittoral organisms in Cardigan Bay, Wales. Environ. Poll. 4:27-35.

The distribution of fluvial zinc in seawater in 5 species of littoral animals, one species of seaweed, and in two species of sublittoral animals, was studied at varying distances from Aberystwyth, a source of zinc pollution. Zinc concentrations, in mg/g dry wt, in the common mussel Mytilus edulis ranged from 0.25 to 0.77; in whelk Thais lapillus, 0.91 to 1.98; in periwinkle Littorina littorea, 0.02 to 0.27; in barnacle Balanus balanoides, 4.5 to 23.1; and in the anemone Actinia equina, 0.16 to 0.60. Zinc content of littoral seaweed Fucus vesiculosus ranged from 0.21 to 0.50 mg/g dry wt. Zinc concentrations in the sublittoral sponge Halichondria panicea ranged from 0.08 to 0.15 mg/g dry wt and in the sublittoral tunicate Botryllus schlosseri, from 0.17 to 0.25 mg/g dry wt. Concentrations of Zn in F. vesciulosus parallel that of seawater. Zinc concentrations in L. littorea and T. lapillus are related to their diet. There is a site/species interaction in the filter feeders M. edulis and B. balanoides but Zn concentration in B. balanoides is always at least 10X higher than in M. edulis. Zinc concentrations in the two sublittoral filter-feeders (H. panicea and B. schlosseri) were significantly different at all localities. Distribution of Zn is discussed in relation to tidal flow, diet and species specificity.

1720. Ishibashi, M., T. Fujinaga, F. Morii, Y. Kanchiku and F. Kamiyama. 1964. Chemical studies on the ocean (part 94) Chemical studies on the seaweeds (19). Determination of zinc, copper, lead, cadmium and nickel in seaweeds using dithizone extraction and polarographic method. Rec. Oceanogr. Works Japan 7(2):33-36.

Algae Eisenia bicyclis, contained Zn, Cu and Pb levels, in mg/kg dry wt, of 112 to 127, 11 to 24, and 7 to 16, respectively. Respective Ni and Cd levels in mg/kg dry wt, of 5 species of algae, were 2.0 and 0.2 for Ulva sp., 3.0 and 0.1 for Desmarestia viridis, 1.5 and 0.3 for Eisenia bicyclis, 2.2 and 0.2 for Gelidium sp., and 4.2 and 0.1 for Acanthopeltis japonica.

1721. Ishibashi, M., T. Fujinaga, T. Yamamoto, T. Fujita, and K. Watanabe. 1965. Zinc and iron in seaweeds. Jour. Chem. Soc. Japan 86:728-733. (In Japanese)

Zinc and iron values in 58 species of aquatic plants, including 8 species from freshwater, are presented. Zinc, in g/kg wet wt, ranged from about 0.11 to 3.95 in marine species and 0.55 to 3.97 in freshwater groups. For iron, values ranged from 0.2 to 12.1 g/kg wet wt for marine species, and 6.7 to 37.4 g/kg for freshwater flora.

1722. Ishibashi, M. and T. Yamamoto. 1960. Inorganic constituents in seaweeds. Rec. Oceanogr. Works Japan 5(2):55-62.

A total of 83 seaweed samples, comprising 44 species were collected from Tomoga-Shima, Wakayama Pref., Japan throughout the year. Metal content, in g/kg dry wt, ranged from 0.2 to 66.6 for Na, 0.3 to 34.3 for K, 5.6 to 42.1 for Ca, 0.3 to 44.3 for Mg, 0.2 to 2.8 for P, 0.07 to 3.41 for Fe and 0.000142 to 0.00253 for Cr. Authors concluded that seaweeds contain elevated levels of Na, Mg and Fe when compared to land plants. Brown seaweeds were high in K and Ca contents while green seaweeds were high in Fe and Cr contents. There were extreme variations in Fe and Mn content among species. Seaweeds with high Fe were also high in Mn and Cr. Approximately half the species analyzed exhibited a value of 3-7 in Fe/Mn atomic ratio. Fe/Cr atomic ratio also showed considerable concentration of iron. The atomic ratio of K/Na is near 1 in all species. The Ca/Mg atomic ratio is below 2 except for Desmarestia viridis. Chromium is much more concentrated in seaweeds than seawater.

1723. Ishibashi, M., T. Yamamoto and T. Fujita. 1964. Chemical studies on the ocean (Part 93) Chemical studies on the seaweeds (18) Nickel content in seaweeds. Rec. Oceanogr. Works Japan 7: 25-32.

Seaweeds collected from shore of Tomogashima, Wakayama Pref., Japan were analyzed for nickel. Among 78 samples representing 38 species, nickel ranged from 0.23 in Grateloupia turuturu to 10.90 mg/kg dry wt in Entermorpha compressa. Total mean value of Ni content was 2.78 mg/kg dry wt; Ni content did not vary with season or habitat. Brown seaweeds (Phaeophyceas) generally contain comparatively high Ni, but some (Eisenia bicyclis, Sargassum gigantelifollium, Sargassum umtortile) which have low iron, aluminum, manganese, chromium and cobalt are low in Ni. Green seaweeds (Chlorophycae) are high in nickel contents and red seaweeds (Rodophycae) generally low. Nickel content of limnetic weeds were higher than that of seaweeds.

1724. Ishibashi, M., T. Yamamoto and F. Morii. 1962. Chemical studies on the ocean (Parts 85) Chemical studies on the seaweeds (11) Copper content in seaweeds. Rec. Oceanogr. Works Japan 6: 157-162.

Copper in 66 samples of 40 species of seaweeds collected from the coast of Tomogashima, Wakayama Pref., Japan, in mg/kg dry wt, ranged from 6.1 to 26.4 in brown seaweeds (Phaeophycae); from 9.2 to 27.7 in green seaweeds (Chlorophycae); and from 7.0 to 26.7 in red seaweeds (Rodophycae).

1725. Ishikawa, M., T. Koyanagi and M. Saiki. 1976. Studies on the chemical behaviour of ^{106}Ru in seawater and its uptake by marine organisms. I. Accumulation and excretion of ^{106}Ru by clam. Bull. Jap. Soc. Sci. Fish. 42(3):287-297.

Accumulation of Ru-106 by Meretrix meretrix lusoria in the form of crude Ru $NO \cdot Cl_x$ and $Ru \cdot Cl_x$, or prepared forms which contained higher radioactivity, reached equilibrium in about 2 weeks. Radioactivity ratios (radioactivity of tissue/g wt ÷ radioactivity of seawater/ml) for prepared Ru-106$\cdot Cl_x$ after 20 days were 24 for mid gut gland, 13 for gill, 4 for digestive tract, 30 for mantle, 2 for shell, and 1 for foot and gonad. Loss of Ru-106 was rapid for soft parts; after 75 days depuration, percentage losses of Ru-106 introduced as prepared $Ru \cdot Cl_x$ were 48 for gill, 69 for mid gut gland, and 52 for digestive tracts.

1726. Jacobson, A.F. 1971. Effect of temperature upon the uptake of ^{144}Ce by Chlamydomonas. Nuclear Sci. Abs. 55162:5427.

Uptake of Ce-144 by Chlamydomonas, a unicellular green alga, was positively correlated with temperature, time, and initial Ce-144 concentration; negatively correlated with biomass; and little affected by cerium specific activity. Temperature and biomass showed the strongest influence; interactions among variables also affected uptake.

1727. Jampol, L.M. and F.H. Epstein. 1970. Sodium-potassium-activated adenosine triphosphatase and osmotic regulation by fishes. Amer. Jour. Physiol. 218:607-611.

Specific activity of Na-K-activated ATPase was high in gills of saltwater teleosts and low in gills of elasmobranchs and freshwater teleosts. Na-K-ATPase activity in gill filaments and intestinal mucosa of freshwater eels Anguilla rostrata, doubled when adapted to seawater for 2 to 3 weeks. Authors suggest that Na-K-ATPase activity varies with Na transport in several organs of teleosts and elasmobranchs under osmotic stress, and conclude that this enzyme plays an important role in active transport of Na across epithelial membranes.

1728. Jangaard, P.M., L.W. Regier, F.G. Claggett, B.E. March and J. Biely. 1974. Nutrient composition of experimentally produced meals from whole argentine, capelin, sand lance, and from flounder and redfish filleting scrap. Jour. Fish. Res. Bd. Canada 31:141-146.

Nutritional analyses, including protein, fat, ash, moisture, minerals, vitamins, available lysine, amino acids, and protein digestibility were conducted on meals produced from whole Atlantic argentines Argentina silus, capelin Mallotus villosus, American sand lance Ammodytes americanus and from filleting scrap from flounders Pleuronectidae sp. and redfish Sebastes marinus. Whole fish meals appeared nutritionally equal to good herring meal. Filleting scrap meals were lower in protein content but nutritional values of the proteins were equivalent to that of herring.

Percentage metal content ranged between 1.8 and 8.8 for Ca, 0.13 and 0.24 for Mg, 1.0 and 1.3 for K, and 0.47 and 0.92 for Na. Concentrations, in mg/kg, ranged from 42 to 199 for Al, 2.5 to 22 for As, 1.6 to 3.9 for Ba, 5.3 to 17.5 for B, 0.13 to 0.34 for Cd, 1.5 to 23.7 for Cr, 0.05 to 0.18 for Co, 2.7 to 14.1 for Cu, 85 to 675 for Fe, 0.8 to 13.4 for Pb, 4.5 to 14.2 for Mn, 0.10 to 0.29 for Hg, 0.05 to 8.8 for Mo, 1.7 to 3.0 for Se, 90 to 416 for Sr, and 74 to 142 for Zn.

1729. Järvenpää, T., M. Tillander, and J.K. Miettinen. 1970. Methylmercury: half-time of elimination in flounder, pike, and eel. Suomen Kemistilehti B. 43:439-442.

Hg-203-labelled methylmercury, as the ionic form nitrate, and as a protein-bound form, was applied perorally, and as the ionic form, injected intramuscularly into flounder Pleuronectes flesus, pike Esox lucius, and eel Anguilla vulgaris. Both forms of methylmercury produced similar elimination rates in flounder and pike: 640 to 780 days. However, IM injection produced a half-time elimination rate of 1,200 ± 400 days in flounder. For eel, the proteinate given perorally had a half-life of 910 days; the ionic form both perorally and IM = 1,030 days.

1730. Jeffrey, R.G. and S.T. Zender. 1974. Ingested lead shot in Washington waterfowl 1973-1974 hunting season. Washington State Dept. Game, Tacoma, Wash.:1-9.

A total of 692 waterfowl gizzards were tested for ingested lead shot in Washington; shot was found in 4%. Assuming a loss of 4 to 12% of birds ingesting shot, theoretical loss would range from 1.5 to 5.0 ducks per 1,000 and therefore appears insignificant.

1731. Jensen, A., B. Rystad and S. Melsom. 1976. Heavy metal tolerance of marine phytoplankton. II. Copper tolerance of three species in dialysis and batch cultures. Jour. Exp. Mar. Biol. Ecol. 22:249-256.

Reduction of growth rate was produced in *Skelotonema costatum*, *Thalassiosira pseudonana*, and *Phaeodactylum tricornutum*, via addition of 10, 25, and 400 µg/l of Cu^{2+}, respectively. When Cu^{2+} was added at levels of 400 and 700 µg/l, cells of *P. tricornutum* in dialysis culture increased Cu content >200X over controls, with ratio of Cu to chlorophyll in cells increasing 150X. All three diatom species showed marked increases when a copper salt was added to batch cultures of algae. Two clones of *S. costatum* showed nearly identical sensitivity to Cu ions, but differed markedly in zinc tolerance.

1732. Jensen, S. and A. Jernelov. 1969. Biological methylation of mercury in aquatic organisms. Nature 223:753-754.

Swedish lake bottom sediments can produce CH_3Hg^{2+} from $HgCl_2$. Over a 7 day period, samples of sediment produced the maximal amount of CH_3Hg^+ (120 µg/kg) when treated with 100 mg/kg $HgCl_2$. Dead fish, *Xiphophorus maculatus*, weighing 5 g and containing 125 µg CH_3Hg^+ converted up to 91 µg to dimethyl mercury in 7 weeks. Authors suggest that formation of the volatile CH_3HgCH_3 may be a factor in redistribution of Hg from aqueous industrial wastes.

1733. Jernelov, A., L. Landner and T. Larsson. 1975. Swedish perspectives on mercury pollution. Jour. Water Poll. Control Fed. 47(4):810-822.

Mercury interactions in aquatic environments emphasizing Swedish contributions are reviewed. Processes examined include: biological methylation of Hg; static and dynamic aspects of accumulation in food chains including role of plankton, filter-feeding bottom invertebrates, and fishes; restoration of Hg-contaminated bodies of water; atmospheric transport; and degradation of methyl-Hg. A bibliography of 52 articles is appended.

1734. Johnson, D.L. 1972. Bacterial reduction of arsenate in seawater. Nature 240:44-45.

Bacterial cultures from Sargasso seawater and Narragansett Bay (R.I.) water were grown in media with sodium arsenite added. As bacterial populations entered the log phase of growth (about 8 h), arsenate began to be replaced by arsenite. Total As remained constant with no accumulation by bacteria. Arsenate reduction rate, calculated at 12 h, was about 10^{-11} μ mol/cell/min. Bacterial arsenate reduction suggests that these processes can occur in open ocean and explain observed arsenite conditions.

1735. Johnson, D.L. and R.S. Braman. 1975. The speciation of arsenic and the content of germanium and mercury in members of the pelagic *Sargassum* community. Deep-Sea Res. 22:503-507.

Arsenic levels in mg/kg wet wt of various components of the pelagic *Sargassum* community were: 4.2 to 19.5 for *Sargassum fluitans* and *S. filipendula*; 5.5 to 6.5 for crab *Portunas*; 12.7 for shrimp; 3.6 for barnacles *Lepas*; and 2.6 for filefish. Average distribution of chemical As species in members of *Sargassum* community was similar to that of surface water: 15% as As^{3+}, 85% as As^{5+} and 1% as alkyl-As. Germanium contents in mg/kg wet wt were: 0.003 to 0.032 for *Sargassum*; 0.002 to 0.025 for shrimp; up to 0.010 for *Portunas*; 0.006 for *Lepas*; and 0.002 for filefish. Total mercury contents, in mg/kg wet wt, were: 0.01 to 0.07 for *Sargassum*; 0.03 to 0.09 for shrimp; <0.01 to 0.03 for *Portunas*; 0.08 for *Lepas*; and <0.01 for filefish.

1736. Jones, D., K. Ronald, D.M. Lavigne, R. Frank, M. Holdrinet and J.F. Uthe. 1976. Organochlorine and mercury residues in the harp seal (*Pagophilus groenlandicus*). Science Total Environment 5:181-195.

Seals, 3 to 14 days old, had total mercury levels in mg/kg wet wt of 0.04 to 0.13 in brain, 0.09 to 0.48 in liver, and 0.04 to 0.34 in kidney. Levels did not differ between sexes. Starvation increased Hg levels in muscle. In comparison with their respective pups, dams had higher Hg levels in brain, liver and blood, with highest overall values in liver (7.6 ± 3.1 mg Hg/kg wet wt). DDT, dieldrin and PCB levels were also examined.

1737. Jones, E.B.G. and D.H. Jennings. 1964. The effect of salinity on the growth of marine fungi in comparison with non-marine species. Trans. Brit. Mycol. Soc. 47:619-625.

Of the 14 marine fungi studied, *Lulworthia floridana* was the only species which showed a requirement for seawater, all others growing better at lower salinities. Growth of all non-marine fungi tested was significantly less in seawater than distilled water. Authors suggest that cation environment may affect vegetative reproduction and nutrient uptake and utilization.

1738. Jones, J.R.E. 1937. The toxicity of dissolved metallic salts to Polycelis nigra (Muller) and Gammarus pulex (L.). Jour. Exp. Biol. 14:351-363.

For P. nigra, a planarian, threshold concentrations of individual salts were: 0.20 N NaCl; 0.15 N $NaNO_3$; and 0.00003 N $PbNO_3$. Survival time was 3 hrs for 0.00002 N $HgCl_2$ exposure. Toxic effects of Hg, Cu and Zn salts at concentrations below isotonicity were due almost entirely to the cation. At concentrations above isotonicity, the anion and osmotic pressure of solution acted as additional lethal factors. For nitrates and sulphates of these heavy metals, toxicity is determined by the product of normality and electrical conductance ratio at that normality. Author suggests that death in heavy metal salt solutions is due to tissue fixation. Salts of the metals of the alkalis and alkaline earths are comparatively harmless below isotonicity, with the exception of salts with a toxic anion such as potassium chromate, which is highly toxic at low concentrations. Death in hypertonic solutions of these metals may be due to osmotic stress. For the amphipod G. pulex, exposure to increasing concentrations of copper nitrate or copper sulphate resulted in rapid decrease in survival time to 58 min at 5×10^{-4} N. Above 0.15 N concentrations, survival time decreased further.

1739. Jones, J.R.E. 1940. A further study of the relation between toxicity and solution pressure, with Polycelis nigra as test animal. Jour. Exp. Biol. 17:408-415.

Toxicity of salts of 18 metals to the planarian P. nigra was determined by 48-h bioassays conducted at 15-18 C. The following levels of toxicity, in mg/l, in increasing order, were observed: Sr 6600, Na 4370, Ca 2600, Mg 970, Mn 700, Pb 400, K 350, Al 110, Co 83, Cr 75, Ni 45, As 40, Zn 30, Cd 2.7, Au 0.6, Cu 0.47, Hg 0.2, Ag 0.15. The position of iron was uncertain, as toxicity of ferric chloride solutions (>20 mg/l) appeared to be due to their acidity. Irregular results were obtained with solutions of barium salts, which effect excessive stimulation of musculature, inducing convulsive movements that eventually result in rupture of body and extrusion of tissues.

There was a decided relationship between solution pressures of metals and degree of toxicity of their salts, the general result being very similar to that obtained earlier with Gasterosteus aculeatus. This relationship suggests that degree of toxicity of ions is largely determined by their affinity for their electrical charges, this affinity determining the readiness with which they tend to abandon the ionic state to enter into chemical combination with protoplasmic compounds.

1740. Jones, J.R.E. 1942. The effect of ionic copper on the oxygen consumption of _Gammarus pulex_ and _Polycelis nigra_. Jour. Exp. Biol. 18:153-161.

For the planarian _P. nigra_, immersion in 80 to 800 mg $CuSO_4$/1, 155 to 311 mg $BaCl_2$/1, 0.850 mg $AgNO_3$/1, or 1.28 mg $HgCl_2$/1, resulted in a preliminary rise in respiratory rate accompanied by inhibition of ciliary locomotion and increased muscular activity. Afterwards, respiration dropped with distintegration observed at 60% of normal oxygen consumption rate. An 8 mg $CuSO_4$/1 solution did not inhibit ciliary locomotion or stimulate muscular activity, but did produce a decrease in oxygen consumption. Similar respiratory responses were observed in _Gammarus pulex_, an amphipod, exposed to 16 and 32 mg $CuSO_4$/1.

1741. Jones, J.R.E. 1947. The oxygen consumption of _Gasterosteus aculeatus_ L. in toxic solutions. Jour. Exp. Biol. 23:298-311.

Stickleback respiration shows an initial increase and subsequent decline to death upon exposure to concentrations (in mg/1) of 13.6 to 54.2 $HgCl_2$, 0.16 $CuSO_4$, or 0.825 $Pb(NO_3)_2$. As the respiration rate declines, rate of operculate movement increases for 180-240/min, then decreases when O_2 intake reaches 38% of normal value. Author suggests that metals cause an increase in blood CO_2 levels, stimulating opercular movements while O_2 intake continues to fall. Eventually, the fish becomes exhausted, respiratory movements fail, and death results.

1742. Jones, L.H., N.V. Jones and A.J. Radlett. 1976. Some effects of salinity on the toxicity of copper to the polychaete _Nereis diversicolor_. Estuarine Coastal Marine Sci. 4:107-111.

Worms were collected from 2 stations in the Humber Estuary in South-West England. Worms from Hessle, which has a salinity range of 7.0 to 15.0^o/oo and a surface sediment Cu level of 62-64 g Cu/kg dry wt, had 96 hr LC-50's of 0.2, 0.44, 0.48 and 0.37 mg Cu/1 at respective salinities of 5.0, 10.0, 17.5 and 34^o/oo. Worms from Skeffling, which has a salinity range of 20.5 to 30.4^o/oo and a surface sediment Cu level of 52 to 56 g Cu/kg dry wt had 96 hr LC-50's of 0.2, 0.45, 0.48 and 0.45 mg Cu/1 in respective salinities of 5.0, 10.0, 17.5 and 34.0^o/oo. Authors suggest that the synergistic effect of increased copper toxicity at high and low salinities is the important lethal factor rather than amount of Cu accumulated.

1743. Jones, M.B. 1975. Effects of copper on survival and osmoregulation in marine and brackish water isopods (Crustacea). Proc. 9th Europ. Marine Biol. Symp.: 419-431.

At salinities of 1 to 100% seawater (100% seawater ≡ 34^{o}/oo) and temperatures of 5 and 10 C, a concentration of 10 mg Cu/l produced mortalities >50% within 5 days among marine isopods *Idotea baltica*, *I. emarginata*, *I. neglecta*, *Eurydice pulchra*, and brackish water species *Jaera stricto* and *J. nordmanni*. Decreasing salinity was associated with increased toxicity. Mortalities did not reach 50% in full seawater with 1 mg Cu/l. Marine species were able to survive in 100% to 40% seawater, and brackish water forms from 100% to 1% seawater, by maintaining hyperosmotic haemolymphs. But 1 mg Cu/l caused a reduction of haemolymph osmotic pressure particularly in dilute salt solutions. It was concluded that Cu acts synergistically with salinity; concentrations of Cu which are sublethal at optimum conditions become increasingly toxic as environmental stress is increased.

1744. Jones, M.B. 1975. Synergistic effects of salinity, temperature and heavy metals on mortality and osmoregulation in marine and estuarine isopods (Crustacea). Marine Biology 30:13-20.

Marine isopods *Idotea baltica*, *I. neglecta*, *I. emarginata* and *Eurydice pulchra*, as well as estuarine *Jaera stricto* and *J. nordmanni* had low mortalities in 100% SW at 5 C when exposed to 10 and 20 mg/l of cadmium ($3\ CdSO_4 \cdot 8H_2O$), zinc ($ZnSO_4 \cdot 7H_2O$) or lead ($Pb(NO_3)_2$) for 120 hours. Decreased salinities or a temperature increase to 10 C reduced LC-50 values. Cadmium, at levels of 20 mg/l, had no effect on osmoregulation of *I. baltica* and *I. emarginata* in 100 and 80% SW at 5 C, but significantly lowered blood osmotic concentration of *I. neglecta* in 80% SW. Zinc, at levels of 20 mg/l did not alter haemolymph osmotic concentration of *I. neglecta* in 100 and 80% SW, but did lower blood osmotic concentration of *I. baltica* in 100% SW. Cd, Zn and mercury ($HgCl_2$) also significantly altered osmoregulatory ability of *J. albifrons* in dilute saline.

1745. Kalk, M. 1963. Absorption of vanadium by tunicates. Nature 198:1010-1011.

In *Ascidia pygmaea*, vanadium is absorbed by passive pharyngeal permeability and by preferential linking of vanadyl ions from the sea to sulphate groups in acid pharyngeal mucus. Neutralized mucus passes by pinocytosis into blood plasma. Accumulation, reduction, and precipitation of V takes place on membranes of cytoplasmic vacuoles, but not at cell surface.

1746. Kameda, K., M. Shimizu and Y. Hiyama. 1970. On the uptake of ^{65}Zn and concentration factor of Zn in marine organisms. II.

Changes in Zn and ^{65}Zn concentration in rearing water. Jour. Radiation Res. 11:44-52.

Zn, in dust, contaminated water at a rate of 2.9 ug/hr/tank. The presence of short-necked clams *Tapes japonica* produced an increase in Zn of 2.0 and 3.1 ug/hr/tank, which is 25 to 30% of the estimated Zn contamination values. This discrepancy is attributed to release of insoluble Zn from clams or a change of Zn to insoluble state due to excretes from clams. In another study, reduction in Zn-65 concentration in water corresponds to amount taken up by *T. japonica*.

1747. Kamiya, M. and S. Utida. 1969. Sodium-potassium-activated adenosine triphosphatase activity in gills of fresh-water, marine and euryhaline teleosts. Comp. Biochem. Physiol. 31: 671-674.

Activities of Na+-K+ ATPase in gills of stenohaline fish were 2 to 5X higher in marine species than freshwater species. Seawater adaptation of euryhaline fish resulted in quadrupling of Na+-K+ ATPase activities.

1748. Kanazawa, T. and K. Kanazawa. 1969. Specific inhibitory effect of copper on cellular division of *Chlorella*. Plant Cell Physiol. 10:495-502.

Cellular division of the freshwater alga *Chlorella ellipsoidea* was inhibited by addition of Cu^{2+} to the medium; inhibition was especially marked at pH 6.3 in range 5.1 to 7.1. The lowest concentration tested of 3×10^{-7} M Cu^{2+} (about 19 ug Cu/l) produced growth inhibition; the highest concentration tested of 3×10^{-6} M Cu^{2+} (about 190 ug/l) completely suppressed growth.

1749. Kania, H.J. and J. O'Hara. 1974. Behavioral alterations in a simple predator-prey system due to sublethal exposure to mercury. Trans. Amer. Fish. Soc. 103:134-136.

After 24-hr exposure to sublethal mercury concentrations of 0.1, 0.05, and 0.01 mg/l Hg^{++}, the ability of mosquitofish *Gambusia affinis* to avoid predation by bass *Micropterus salmoides* was impaired. Fish exposed to 0.005 mg/l of Hg^{++} were not affected. Degree of effect showed a positive correlation with mercury concentrations. Behavioral alterations occurred when mean body concentrations were as low as 0.67 mg of Hg/kg wet wt of whole fish.

1750. Kayser, H. 1976. Waste-water assay with continuous algal cultures: The effect of mercuric acetate on the growth of some marine dinoflagellates. Marine Biology 36:61-72.

Effect of mercuric acetate was studied with the dinoflagellates *Scrippsiella faeroense*, *Prorocentrum micans*, and *Gymnodinium splendens*. Impairment of growth rates, in vivo chlorophyll fluorescence, maximum cell densities and morphological changes were criteria for assessing sublethal influences. Tests were made using batch and continuous culture techniques. Addition of Hg at concentrations of 0.001 mg/1, reduced relative growth rates of *S. faeroense*. At 0.05 mg Hg/1, *S. faeroense* and *P. micans* populations recovered from initial declines and showed new growth. Morphological variations were observed in *S. faeroense*, which responded (even in sublethal concentrations) by bursting it's thecae, releasing naked motile cells and forming vegetative resting stages.

1751. Kazlauskene, O.P. and M.A. Shcherbina. 1975. Alteration in the organic and mineral composition of the chyme in yearling pond carp (*Cyprinus carpio*) following the addition of chalk to the diet. Jour. Ichthyology 15:804-811.

Addition of 2 or 5% chalk to diet of carp resulted in a decrease in protein and carbohydrate contents of chyme and an increase in chyme levels of lipids and minerals, especially magnesium. Authors suggest that Ca competes with Mg uptake in absorption processes of alimentary tract.

1752. Keckes, S., Z. Pucar, and L. Marazovic. 1966. The influence of the physico-chemical form of ^{106}Ru on its uptake by mussels from sea water. *In* Aberg, B. and F.P. Hungate (eds.). Radioecological Concentration Processes. Proc. Inter. Symp. Stockholm, 1966, Pergamon Press, New York: 993-994.

Mussels *Mytilus galloprovincialis* concentrated Ru-106 by about 50 in soft parts and 4 in shell during 5 days of exposure to a Ru-106 nitrate complex. Factors of 5 for soft parts and [illegible] for shell were observed with a Ru-106 chloride complex during a similar period.

1753. Keeney, W.L., W.G. Breck, G.W. Vanloon and [illegible].A. Page. 1976. The determination of trace metals in *Cladophora glomerata* - *C. glomerata* as a potential biological monitor. Water Research 10:981-984.

Metal levels, in mg/kg dry wt, of the alga Cladophora collected from a remote island in Lake Ontario and from a shore site near Kingston, Ontario, were respectively 8.2 and 23.7 for Zn, 1.4 and 3.9 for Cd, 12.2 and 9.5 for Pb, and 6.4 and 7.2 for Cu. In both instances concentration factors were in the range 10^3 to 10^4.

1754. Kelly, T.M., J.D. Jones, and G.R. Smith. 1975. Historical changes in mercury contamination in Michigan walleyes (Stizostedion vitreum vitreum). Jour. Fish. Res. Bd. Canada 32:1745-1754.

Mercury concentrations in Michigan walleyes (teleosts) were more variable among localities than between recent and historical samples within localities. Mercury concentrations, in mg/kg wet muscle, in walleyes of 280 mm length collected between 1865 and 1936 vs 1971 were 0.17 vs 0.18 for Houghton Lake specimens, 0.143 vs 0.191 for Lakes Cadillac and Mitchell, 0.21 vs 0.15 for Bear Lake, 0.21 vs 0.25 for Saginaw Bay, 0.24 vs 0.30 for Lake Gogebic, and 0.43 vs 0.48 for Isle Royale. Recent walleyes of 307 mm length taken from the Western Basin of Lake Erie had a mean Hg level in muscle of 0.45 mg/kg, whereas specimens collected from 1865 to 1936 had 0.35 mg Hg/kg muscle tissue.

Hg concentration in walleye muscle from recent and old museum collections was positively correlated with age and size. Considerable variation in concentration existed not only between geographic localities, but within populations, and even within subsamples of the same tissue.

1755. Kennedy, V.S. 1976. Arsenic concentrations in some coexisting marine organisms from Newfoundland and Labrador. Jour. Fish. Res. Bd. Canada 33:1388-1393.

Inorganic arsenic concentrations in seawater and mud, and total As concentrations in bodies of shrimp, zooplankton, and fish from northern Newfoundland and southern Labrador were measured. For shrimp, a positive relation existed between concentration and carapace length for Pandalus borealis and P. montagui and a negative relation for Eualus macilentus; these contained mean As concentrations of 7.3-11.5, 7.4-10.8, and 6.7 mg/kg wet wt, respectively. There was no correlation between concentrations in shrimp eggs and carapace length. Zooplankton, hyperiids and gammarids contained more As at 2.6 and 6.6 mg/kg wet wt, respectively, than copepods and euphasiids at 1.4 and 1.8 mg/kg wet wt. In fish, concentrations in muscle of American plaice Hippoglossoides platessoides at 4.4 mg As/kg wet wt, were higher than those of redfish Sebastes marinus, Atlantic cod Gadus morhua, and turbot *Rheinhardtius hippoglossoides*, all of which had mean muscle concentrations of 0.8 mg As/kg wet wt. There was no evidence of increasing As concentrations through higher levels of the food chain.

1756. Kennedy, W.A. and M.S. Smith. 1972. Sablefish culture-progress in 1971. Fish. Res. Bd. Can. Tech. Rep. 309:15 p.

Sablefish *Anoplopoma fimbria*, reared and cultured in the laboratory, were analyzed for Hg, along with fish used to feed sablefish. Sablefish fed a diet of 50% herring - 50% dogfish contained 0.57 mg Hg/kg after 12 months and 1.29 mg/kg after 28 months. For 24-month-old sablefish fed 62% herring and 29% chicken wastes, the average Hg level was 0.46 mg/kg. Mean Hg level in mg/kg was 0.39 for dogfish *Squalus suckleyi*, 0.05 for herring *Clupea pallasii*, 0.09 for hake *Merluccius productus*, 0.04 for whiting *Theragra chaleogrammus* and 0.04 for arrowtooth flounder *Atheresthes stomias*. High levels of Hg found in two lots of sablefish fed 50% dogfish was attributed to high levels of Hg in dogfish.

1757. Kerstetter, T.H., L.B. Kirschner and D.D. Rafuse. 1970. On the mechanisms of sodium ion transport by the irrigated gills of rainbow trout (*Salmo gairdneri*). Jour. Gen. Physiol. 56: 342-359.

Sodium uptake by trout gills obeyed a Michaelis-Menten relation, with a Km of 0.46 mM and proceeded unimpaired in absence of penetrating counterions; this could indicate existence of a coupled cation exchange mechanism. Ammonia output was same as Na^+ influx when external Na^+ concentration was 1 mM; this correlation did not hold at higher or lower Na^+ influxes. As Na^+ influx increased, pH declined in irrigating medium; authors suggest that exchanging cation is hydrogen. Acetazolamide, a Na^+ uptake inhibiter, also prevented downward pH shift. Potential across gill was ∿10 mv, body fluids positive, in NaCl solutions up to 10 mM, and was little affected by changes in lower Na^+ concentrations.

1758. Ketchum, B.M. and V.T. Bowen. 1958. Biological factors determining the distribution of radioisotopes in the sea. *In* Proc. of Second Ann. U.N. Int. Conf. Peaceful Uses of Atom. Energy - Vol. 18. Waste Treat. Environ. Aspect of Atomic Energy, Geneva: 429-433.

Concentration factors (CF) for isotopes of Cs, Sr, Fe, Co, Zn, and Cd by various groups of marine biota are presented. CF for copepod *Centropages* sp. and Cs is 0.1 to 1; for Co it is 600. For the copepod *Calanus* sp. CF is 0.1 to 1 for Cs, 0.28 for Sr, 2.5 X 10^4 for Fe, and 200 for Co. For squid *Ommastrephes* CF is 0.1 for Cd, 0.3 for Sr, 10^4 for Fe, 200 for Co, 2 X 10^4 for Zn, and 2 X 10^5 for Cs. For the chaetognath *Sagitta* CF is 70 for Sr, 5 X 10^4 for Fe, and 10^4 for Co. Other CF were 0.3 and 800 for Sr and Co in krill *Euphausia*, and 60 for Co in the tunicate *Salpa* sp.

1759. Khan, K.U. and Y. Hiyama. 1964. Mutual effect of Sr-Ca upon their uptake by fish and freshwater plants. Records Oceanog. Works Japan 7:107-122.

Six species of freshwater teleosts, molluscs and crustaceans, 6 species of freshwater algae and plants, and 3 species of marine fish and shrimps were reared in various concentrations of stable Ca and Sr labeled by Sr-89 and Ca-45 to measure uptake through epithelial tissues. Results fit exponential function $y=a\ (1-e^{-bt})$ where y was concentration factor at time t and a,b were constants. In smaller sized fishes, the concentration factor ranged between 30 and 40 (*Cyprinus carpio*, *Oryzias latipes*); in large fishes the CF ranged between 5 and 10 (*Misgurnus anguillicaudatus*, *Carassius auratus*); in shrimps *Xiphocardina compressa*, the CF was about 50. With exception of *Spirogyra* sp. and *Myriophyllum verticulatum*, where CF ranged from 8 to 10, the CF in plants was 30 to 40. Strontium at 500 mg/l was lethal for all fish. Uptake by animals and plants was highest for both Ca-45 and Sr-89 in lowest solution of Ca (1 mg/l) and Sr (1 mg/l), due to nutritional needs of these elements. Goldfish subjected to chronic feeding of Ca-45 and Sr-89 reached highest concentrations on 21st day.

1760. Kharkar, D.P., J. Thomson, K.K. Turekian and W.O. Forster. 1976. Uranium and thorium decay series nuclides in plankton from the Caribbean. Limnol. Oceanog. 21:294-299.

Zooplankton, predominantly calanoids and cyclopoids, from the Caribbean were analyzed for U-238, U-234, Th-232, Th-228, Ra-228, Ra-226, Pb-210 and Po-210. Concentration factors in zooplankton relative to seawater (liters of SW eq. to 1 g plankton) were: 970 for Po-210; 24 for Pb-210; 4.9 for Ra-226; 0.17 for U-238; and 20 for Th-228. Pb-210 and Th-228 have similar concentration factors and are comparable to reported fiber-scavenging experimental data on Pb-210 and Th-234. Certain nuclides, such as Po-210, are concentrated more efficiently by zooplankton but may be released rapidly to solutions in the mixed layer. Actual flux of particles carrying radionuclides from mixed layer to depth unidirectionally cannot have the Po-210:Pb-210 ratio of bulk zooplankton; thus, dominant transport agent for these nuclides from mixed layer to depth cannot be unmodified zooplankton debris.

1761. Kiceniuk, J. and J.E. Phillips. 1974. Magnesium regulation in mosquito larvae (Aedes campestris) living in waters of high $MgSO_4$ content. Jour. Exp. Biol. 61:749-760.

Larvae of A. campestris live in natural waters with seasonal variations in magnesium content of 1 to more than 100 mM, while haemolymph levels of Mg vary only from 1.5 to 4 mM. Field and laboratory observations suggest an upper tolerance limit between 95 and 125 mM Mg. Using observed mean drinking rates of 0.1 to 0.2 ul/h/mg (300% of total body wt/day), rate of Mg excretion per larvae is 54 n mol/h and rate of ingestion is 42 to 83 n mol/h, with ingested fluid and magnesium ions being largely absorbed into haemolymph via midgut. Urinary concentrations of Mg^{2+} ions was up to 2.8X greater than external media and up to 23X haemolymph. It is suggested that Mg is not excreted across the general body surface; rather, malpighian tubules and hindgut are largely responsible for Mg elimination from haemolymph.

1762. Kifer, R.R. and W.L. Payne. 1968. Selenium content of fish meal. Feedstuffs 31 Aug 68:32.

Selenium contents in mg/kg, were determined for menhaden (1.22 to 3.98), Peruvian anchovetta (1.05 to 1.71), and Norwegian herring (1.73 to 3.43). Authors suggest that addition of 3 to 5% fish meal to diets of chickens would meet their Se requirements of 0.05 to 0.1 mg/kg Se.

1763. King, E.N. 1965. The oxygen consumption of intact crabs and excised gills as a function of decreased salinity. Comp. Biochem. Physiol. 15:93-102.

Respiratory rate of whole crabs in 50% seawater compared to that of normal seawater (S=36°/oo) decreased 50% in Maja verrucosa, and 30% in Libinia emarginata, both stenohaline species, and increased 33% in Carcinus mediterraneus and 53% in Callinectes sapidus, both euryhaline species. In excised gills under similar conditions, endogeneous respiratory rate increased 6% in Maja, 10% in Callinectes collected in seawater (36°/oo), 30% in Callinectes collected in brackish water (12°/oo) and did not change significantly in Carcinus. Gills of Carcinus and Callinectes from both habitats showed a 2.5% increase in water content on incubation in 50% seawater. In seawater, gill respiration of brackish water Callinectes was significantly higher than Callinectes from marine environments.

1764. Kinne, O. 1964. The effects of temperature and salinity on marine and brackish water animals. II. Salinity and temperature salinity combinations. Oceanogr. Mar. Biol. Ann. Rev. 2:281-339.

Literature on physiological responses of organisms to altered salinities is reviewed with emphasis on total osmo-concentration, relative proportion of internal solutes, ability to absorb and retain dissolved gasses, and density and viscosity modifications. Salinity factors may affect reproductive, developmental, and growth capabilities of an organism. Ionic regulation mechanisms are discussed. Adaptations for salinity stresses are examined in terms of genetic capabilities. Combined effects of temperature and salinity are considered in terms of metabolism and activity, reproduction, structure, and distribution. Animals examined include coelenterates, echinoderms, annelids, crustacea, molluscs, insects, sipunculids, elasmobranchs and fish. A total of 382 references are listed.

1765. Kirschner, L.B., L. Greenwald and T.H. Kerstetter. 1973. Effect of amiloride on sodium transport across body surfaces of freshwater animals. Amer. Jour. Physiol. 224:832-837.

Inhibition of Na influx in trout *Salmo gairdneri*, frog *Rana pipiens*, and crayfish *Procambarus* spp., by 79%, 46% and 90%, respectively, occurred upon addition of 10^{-4} M amiloride to external solution. Treatment had no effect on efflux across body surface.

1766. Kirschner, L.B., L. Greenwald, and M. Sanders. 1974. On the mechanism of sodium extrusion across the irrigated gill of sea water-adapted rainbow trout (*Salmo gairdneri*). Jour. Gen. Physiol. 64:148-165.

Sodium efflux across irrigated trout gill was rapid in seawater, but only about 25% the freshwater value. The difference correlated with a change in the potential difference across gill (TEP); which was about + 10 mV in SW, but - 40 mV in FW. Both flux and electrical data indicated that trout gills are permeable to a variety of cations including Na^+, K^+, Mg^{2+}, choline, and Tris. They are less permeable to anions, with the ratio of permeability coefficients $P_{Na}:P_K:P_{Cl}$ estimated as 1:10:0.3. The TEP was shown to be a diffusion potential determined by these permeabilities and the extant ionic gradients in SW, FW, and other media. Na efflux appeared to be diffusive in all experiments. A model is proposed which accounts for passive net diffusion of Na^+ and K^+ across gill and dependence of TEP on external concentrations. The question of whether there is an active component to Na extrusion is still unresolved.

1767. Klass, E., D.W. Rowe and E.J. Massaro. 1974. The effect of cadmium on population growth of the green alga Scenedesmus quadracauda. Bull. Environ. Contamin. Toxicol. 12:442-445.

The freshwater algae S. quadracauda was grown in Cd concentrations ranging from 0.0 to 610 μg/l. Mean population size was not affected below 6.1 μg/l, but was inhibited at concentrations of Cd^{2+} of 6.1 μg/l and above. Cd levels of 61 μg/l and higher severely inhibited growth. Enzyme inhibition is suggested to be a mechanism of growth retardation. It was concluded that the 10 μg Cd/l upper limit for drinking water should be revised downward.

1768. Klaunig, J., S. Koepp and M. McCormick. 1975. Acute toxicity of a native mummichog population (Fundulus heteroclitus) to mercury. Bull. Environ. Contamin. Toxicol. 14:534-536.

Mummichogs, estuarine cyprinodontiform teleosts, exposed to 0.86 mg $HgCl_2$/l for 96 h survived with no apparent deleterious effects. Levels of 1.15 mg $HgCl_2$/l to the 96 h LC-50 of 2.0 mg $HgCl_2$/l produced the following among survivors: sluggish behavior, uncoordinated swimming movements, and pronounced negative phototaxy. Increased operculate movement and death within 24 h occurred during immersion in 4.60 mg $HgCl_2$/l.

1769. Kleerekoper, H., J.B. Waxman and J. Matis. 1973. Interaction of temperature and copper ions as orienting stimuli in the locomotor behavior of the goldfish (Carassius auratus). Jour. Fish. Res. Bd. Canada 30:725-728.

Movements of single goldfish were monitored in a free choice situation comprising zones of laboratory water, or water containing 0.010 mg Cu/l as $CuCl_2$, each at two temperatures, 21.1 ± 0.1 and 21.5 ± 0.1 C. Fish entered the Cu zone at 21.1 C significantly less frequently and spent less time there per entry as compared to Cu-free zone. The Cu zone at 21.5 C became significantly "attractive" to fish in terms of both frequency of entry and time spent. Laboratory water at 21.5 C was "attractive" to fish but became significantly more so in presence of 0.010 mg Cu^{2+}/l.

1770. Klein, D.H. and E.D. Goldberg. 1970. Mercury in the marine environment. Environ. Sci. Technol. 4:765-768.

Mercury levels in crabs, whelks, and scallops are several orders of magnitude greater than comparable volumes of seawater. Higher values of mercury are present in sediments near sewer outfalls as compared to similar deposits further removed; this was reflected in mercury levels of benthic organisms.

1771. Klemmer, H.W., C.S. Unninayer and W.I. Ukubo. 1976. Mercury content of biota in coastal waters in Hawaii. Bull. Environ. Contamin. Toxicol. 15:454-457.

Total mercury in mg/kg wet wt in 58 different species of fish, molluscs, crustaceans, and echinoderms, was determined. Concentrations ranged from undetectable (<0.01 mg/kg) in 26% of samples to 1.0 mg/kg in one sample. The overall mean value was 0.08 mg/kg. For those organisms having a feeding habit in direct contact with sediment, 0.022 mg Hg/kg was found in herbivores, 0.058 mg Hg/kg for omnivores and 0.075 for carnivores. For organisms feeding above the sediment-water interface, higher values were found in herbivores (0.036), omnivores (0.070) and carnivores (0.080).

1772. Knauer, G.A. 1970. The determination of magnesium, manganese, iron, copper and zinc in marine shrimp. Analyst 93:476-480.

Mean metal content in pooled samples of two species of penaeid shrimp, Penaeus aztecus and P. duorarum, were determined. Values in mg/kg dry wt were 3520 for Mg, 6.1 for Mn, 50 for Fe, 47 for Cu, and 62 for Zn.

1773. Knauer, G.A. and J.H. Martin. 1973. Seasonal variations of cadmium, copper, manganese, lead, and zinc in water and phytoplankton in Monterey Bay, California. Limnol. Oceanogr. 18:597-604.

Mean (range) metal contents for surface water samples collected over 1 year in Monterey Bay, in μg/l, were: Cd 0.15 (0.02 to 4.7); Cu 1.3 (0.5 to 4.5); Mn 0.6 (0.3 to 3.5); Zn 6.5 (0.7 to 35); and Pb 0.9 (0.2 to 2). Maximal values of phytoplankton metal contents, in mg/kg dry wt, were: Cd 7, Cu 50, Mn 35, Zn 750, and Pb 40. Metal levels in nearshore surface waters appeared to be more dependent upon hydrographical fluctuations than biological factors, except for Cd, which decreased during peak phytoplankton productivity. Most variability and highest concentrations of metals in phytoplankton occurred during peak upwelling pulses. Phytoplankton metal levels appear to be inversely related to biomass. For surface water between Hawaii and Monterey, levels of Cu, Mn, and Zn were usually higher inshore than offshore especially during periods of strong upwelling. Concentrations of Cd and Pb were almost always an order of magnitude higher inshore.

1774. Knauss, H.J. and J.W. Porter. 1954. The absorption of inorganic ions by *Chlorella pyrenoidosa*. Plant Physiol. 29:229-234.

Radiotracers were used to determine Ca, Fe, Mn, Zn, Cu, and Sr in *C. pyrenoidosa* when nutrient concentration of element varied. Absorption by algae was directly proportional to concentration of element in nutrient solution. The percent of nutrient element removed by cells ranged from 75 to 95% for Fe, 64 to 77 for Mn, 0.22 to 0.34 for Ca, 0.61 to 0.79 for Sr, 15.6 to 39.6 for Cu, and 5.8 to 12.6% for Zn.

1775. Kobayashi, J. 1971. Relation between the "itai-itai" disease and the pollution of river water by cadmium from a mine. Adv. Water Poll. Res. 1:1-32.

"Itai-itai" (ouch ouch) disease is an unusual chronic disease affecting residents of the Jintsu River district in Toyama Prefecture, Japan. Afflicted individuals had severe osteomalacia and suffered intense pain. Since World War II about 200 cases have been discovered, half of whom died, being most prevalent among older women. Post-mortem analyses showed high residues of Cd, Zn and Pb in tissues of victims. The cause of the disease was presumed associated with mine wastewater containing heavy metals discharged into the drinking water supply (Jintsu River). Associated with wastewater discharges was damage to rice plants irrigated by the Jintsu River. There was a heavy accumulation of Zn, Pb and especially Cd in patients' bones and internal organs, soil, and plants. From these and other studies author concluded that "itai-itai" disease was induced by cadmium in the wastewater from a mine.

1776. Kobayashi, N. 1971. Fertilized sea urchin eggs as an indicatory material for marine pollution bioassay, preliminary experiments. Publ. Seto Mar. Biol. Lab. 18(6):379-406.

As part of a larger investigation on marine water quality, author investigated effects of various metals on sea urchin embryology. All studies were conducted at 28 C with *Anthocidaris crassispina* in static, raw seawater. Values bracketing the "no effect," "frank effect" level, in mg/l were: 0.023-0.046 for Hg (as $HgCl_2$); 0.009-0.018 for Hg (as phenyl mercuric acetate); 0.8-1.6 for Cd (as $CdCl_2 \cdot 2\ 1/2H_2O$); 0.6-1.2 for Ni (as $NiCl_2 \cdot 6H_2O$); 0.065-0.13 for Zn (as $ZnCl_2$); 0.05-0.1 for Cu (as $CuSO_4 \cdot 5H_2O$); 17-170 for cobalt (as cobalt acetate); 6.6-13.2 for Mn (as $MnCl_2 \cdot 4H_2O$); 4.2-8.4 for Cr^{+3} (as $CrCl_3 \cdot 6H_2O$); 1.1-2.2 for Pb (as lead acetate); 2.1-4.2 for As (as As_2O_5); and 37-75 for B (as H_3BO_3).

1777. Koblick, D.C. and C.D. Rufus. 1976. The role of sodium and calcium ions in osmoregulation in Hydra littoralis. Jour. Exp. Zool. 197:331-338.

Frequency of column contraction in Hydra as a measure of rate of water elimination is maximal at 5 X 10^{-4} M Na^+. This falls off markedly at higher and lower concentrations, even though total medium osmotic pressure is kept constant by replacement with K^+. Reduction in Ca^{2+} concentration causes a reduction in frequency of column contractions. This reduction is half-maximal at about 4.8 X 10^{-4} M Ca^{2+}. Authors suggest that Na^+ plays a regulatory role in the mechanism of extrusion of water and salts from cells to the gastrovascular cavity.

1778. Koch, H.J., J.C. Evans and E. Bergstrom. 1959. Sodium regulation in the blood of parr and smolt stages of the Atlantic salmon. Nature 184:283.

On abrupt transfer from fresh to seawater at the same temperature, all 2 yr-old parr of Salmo salar died within 26 hrs. No individuals in smolt stage, whether 1 or 2 yr old, died during the same treatment. Upon transfer parr showed rising Na levels in blood; smolt blood Na levels decreased to original level within 120 hrs.

1779. Koczy, F.F. and H. Titze. 1958. Radium content of carbonate shells. Jour. Mar. Res. 17:302-311.

Shells of 18 species of recent molluscs contained 0.359 X 10^{-10} to 3.58 X 10^{-10} g Ra/kg Ca. Exoskeleton of 4 species of recent crustacea contained 2.0 X 10^{-10} to 8.1 X 10^{-10} g Ra/kg Ca. Fresh phytoplankton contained 606 X 10^{-10} g Ra/kg Ca. It was estimated that apparent half-life of Ra is one-third of natural decay constant due to removal by biological processes.

1780. Koeman, J.H., W.S.M. van de Ven, J.J.M. de Goeij, P.S. Tjioe and J.L. van Haaften. 1975. Mercury and selenium in marine mammals and birds. Science Total Environ. 3:279-287.

In marine mammals a 1:1 Hg/Se molecular increment ratio and an almost perfect linear correlation between mercury and selenium was found. Methylmercury, which tends to accumulate in fish and in food chain more rapidly than other mercury compounds, comprised only a minor portion of mercury in marine mammals, namely 2 to 14% in liver and brain of adult seals. Due to these facts and that the Hg/Se ratio differs markedly in fish which make up diet of seals, it is proposed that marine mammals are able to detoxify methylmercury by a specific chemical mechanism which involves Se. In fish-eating marine birds, the Hg content is low compared to marine mammals, with no marked difference between juvenile and adult birds. There was no statistical correlation between Hg and Se in marine birds tested.

1781. Koirtyohann, S.R., R. Meers and L.K. Graham. 1974. Mercury levels in fishes from some Missouri lakes with and without known mercury pollution. Environ. Research 8:1-11.

Mercurial fungicides used for golf greens maintenance can lead to elevated levels of Hg in fish from lakes receiving greens drainage. Largemouth bass Micropterus salmoides, was the most sensitive indicator with Hg levels ranging from 1 to 7 mg/kg wet wt in fish taken from lakes receiving drainage from treated greens. Mercury levels in other fish species, in mg Hg/kg wet wt, ranged from 0.27 to 1.03 in green sunfish Lepomis cyanellus, 0.37 to 1.11 in bluegill Lepomis macrochirus, and 0.19 to 0.78 in channel catfish Ictalurus punctatus. Background Hg levels in largemouth bass from impoundments in central Missouri are 0.1 to 1.2 mg/kg wet wt, depending on size and other factors. Many lakes with no known source of Hg contamination produce bass which contain significantly more than 0.5 mg/kg of Hg.

1782. Koivusaari, J., I. Nuuja, R. Palokangas and M.-L. Hattula. 1976. Chlorinated hydrocarbons and total mercury in the prey of the white tailed eagle (Haliaeetus albicilla L.) in the Quarken Straits of the Gulf of Bothnia, Finland. Bull. Environ. Contamin. Toxicol. 15:235-241.

Eagle populations have been dwindling and this appears to be correlated with high concentrations of DDT, PCB and mercury (up to 26 mg/kg wet wt) in dead birds and addled eggs. Determination of PCB, DDE, DDT and Hg in prey species of eagle showed Hg (in mg/kg wet wt) in fish muscle ranged from 0.20 to 0.68; Hg in pectoral muscle of prey birds ranged from 0.05 to 0.93.

1783. Kolehmainen, S.E. 1972. The balances of Cs-137, stable cesium and potassium of bluegill (Lepomis macrochirus Raf.) and other fish in White Oak Lake. Health Physics 23:301-315.

Residues, uptake, and elimination rates of Cs-137, stable Cs and K were determined over a 19 month period in bluegill and 6 other fish species inhabiting a small radioactively-contaminated lake in Oak Ridge, Tennessee. Cs-137 concentrations increased 4X in bluegills over the weight range 1 to 70 g, but stable Cs concentration decreased slightly with increasing fish size. In all species, concentrations of

Cs-137 and stable Cs cycled seasonally with a minimum in summer and a maximum in winter. Cs-137 concentration was highest in species feeding on prey with high Cs-137 content. K concentrations decreased slightly with increasing fish size, but did not fluctuate seasonally. In bluegill the absorbed Cs-137 was eliminated by a two-component exponential process. At 15 C, the rates were 0.0912/day (fast component) and 0.00370/day (slow component) in bluegill above 70 g. The proportion of body burden eliminated by fast component was 37% after a single feeding of food contaminated with Cs-137; at equilibrium, proportion of body burden eliminated by fast component was only 2.3%. Rates of elimination decreased with the increasing weight of bluegill. There were no significant differences in rates of slow component between fish in equilibrium with Cs-137 intake and those receiving a single feeding of Cs-137. K was eliminated at a single exponential rate in bluegill: 0.019/day at 15 C. Intake rates of Cs-137, stable Cs and K in bluegill were calculated on basis of seasonal changes in body burden and elimination rates.

1784. Komura, I., T. Funaba and K. Izaki. 1971. Mechanism of mercuric chloride resistance in microorganisms. II. NADPH-dependent reduction of mercuric chloride and vaporization of mercury from mercuric chloride by a multiple drug resistant strain of *Escherichia coli*. Jour. Biochem. 70:895-901.

Ability to vaporize a Hg-203 compound from Hg-203Cl_2 was demonstrated in crude cell-free extracts of a strain of *E. coli* which had multiple drug resistance. NADPH was essential for vaporization, while NADH had only a slight stimulating effect and $NADP^+$ had no effect. Oxidation of NADPH dependent on $HgCl_2$ was also demonstrated in crude extracts, but $HgCl_2$-dependent NADH oxidation could be demonstrated only when a partially purified enzyme preparation was used. It was suggested that NADPH, and to a lesser extent NADH, act as electron donors for enzymatic reduction of $HgCl_2$ prior to vaporization. This appears to be a mechanism of resistance to $HgCl_2$ in *E. coli* strains having multiple drug resistance.

1785. Komura, I. and K. Izaki. 1971. Mechanism of mercuric chloride resistance in microorganisms. I. Vaporization of a mercury compound from mercuric chloride by multiple drug resistant strains of *Escherichia coli*. Jour. Biochem. 70:885-893.

Three strains of *E. coli* possessing multiple drug resistance were resistant also to $HgCl_2$, though sensitive to Ni, Co, Cd and Zn. As was true for resistance to chloramphenicol and tetracycline, the $HgCl_2$ resistance could be transferred from a resistant strain of *E. coli* to sensitive strains of *E. coli* and *Aerobacter aerogenes*.

Resistant strains could grow in 5.4 mg $HgCl_2$/l, whereas a sensitive strain failed to grow in 2.7 mg $HgCl_2$/l. Cells of resistant strains vaporized a form of radioactive Hg when incubated with Hg-203Cl_2, while cells of sensitive strain showed no such activity.

1786. Kondo, I., T. Ishikawa and H. Nakahara. 1974. Mercury and cadmium resistances mediated by the penicillinase plasmid in *Staphylococcus aureus*. Jour. Bacteriol. 117(1):1-7.

Mercury resistance in *S. aureus* mediated by penicillinase (Pc-ase) plasmid was based on changing the ion incorporated in the cell into a somewhat innocuous form. This process was independent of temperature and appeared controlled by an inducible enzyme. Killing effect of Hg salts was not influenced by $MgCl_2$, $CaCl_2$, $MnCl_2$ and NaCl. No vaporization of Hg was found in the case of Hg resistance in staphylococci. Resistance to Cd ion was mediated by some protective mechanism to retain the ion outside the cell. Pc-sensitive organisms incorporated Cd ions into cells, whereas Pc-ase plasmid-carrying organisms did not. Incorporation of Cd was temperature dependent and did not take place at 4 C; Pc-sensitive organisms as well as Pc-resistant organisms were resistant. Addition of $CaCl_2$ could eliminate killing effect of $CdCl_2$ with a dose-effective response.

1787. Kopfler, F.C. and J. Mayer. 1967. Studies of trace metals in shellfish. *In* Proc. Gulf and South Atlantic States Shellfish Sanitation Res. Conf.: 67-80.

Polarographic analyses of 136 oyster samples from South Atlantic and Gulf Coast showed an average copper content of 19 mg/kg wet wt with a range of 1-55 mg/kg; mean zinc content was 230 mg/kg with a range of 24-820 mg/kg. At one sampling station cadmium was 1.12 mg/kg, chromium at trace levels, and lead undetectable. Zinc and Cu levels at this station were 495 and 27 mg/kg wet wt, respectively. Authors concluded that Cu content in oysters from these areas had not increased significantly since 1932 values, and that no Cu and Zn levels approached proposed interim guidelines of 100 Cu and 1500 Zn mg/kg wet meats.

1788. Kormondy, E.J. 1965. Uptake and loss of zinc-65 in the dragonfly *Plathemis lydia*. Limnol. Oceanogr. 10(3):427-433.

For early, middle, and late instar larvae of the dragonfly exposed to concentrations of 0.005 to 0.5 μ Ci Zn-65 Cl_2/ml water, the rate and amount of uptake were independent of temperature with equilibrium occurring in 24-48 hr. However, loss rate was significantly greater at 10 C than at 20 and 30 C. Uptake and loss rates were independent of body size (age), but amount concentrated was inversely related to body size, the coefficient of accumulation being 68 in small larvae and 28 in large larvae. Total uptake was directly proportional to isotope availability in medium. Loss rates in field and laboratory did not differ. Loss rate in dead animals was the same as in live larvae: 95% of initial activity remained on the cast exuvium at molting and final metamorphosis. Uptake in dragonfly larvae occurs by surface adsorption or cation exchange, thereby imposing constant use of Zn-65 as an indicator of metabolic activity in energy flow studies. But Odonata may effectively redistribute Zn, the bulk of which localizes in upper sediments.

1789. Koryak, M., M.A. Shapiro and J.L. Sykora. 1972. Riffle zoobenthos in streams receiving acid mine drainage. Water Research 6:1239-1247.

In stream localities immediately influenced by mine drainage, with pH's as low as 2.6, total acidity as high as 1130 mg/l as $CaCO_3$, and average total iron up to 89 mg/l, the effect of acid mine wastes on ecology and composition of benthic fauna is similar to effect of organic pollution, i.e., high numbers of individuals comprised of a few species. In zones of active neutralization, where iron hydroxides are deposited, species diversity slightly increases but biomass is very low. The most numerous invertebrates in the stream sections exhibiting high acidity, low pH, and high Fe, are midge larvae, especially Tendipes gr. riparius. Number of insect groups present increases steadily with progressive neutralization until amphipods and oligochaetes appear, indicating considerable improvement in water quality. Supply of desirable benthic fish food (Tendipis sp.) is very high in parts of stream where low pH, high acidity, and high ferrous iron concentrations prevail. Unfortunately, fish cannot survive under these conditions to utilize this abundant food supply. In less acidic zones, where fish could possibly survive, deposition of ferric iron drastically diminishes total biomass of benthic organisms and therefore severely limits fish populations.

1790. Kosta, L. and A.R. Byrne. 1969. Activation analysis for mercury in biological samples at nanogram level. Talanta 16: 1297-1303.

Fish solubles contained between 68 and 76 nanograms Hg/g.

1791. Kramer, H.J. and B. Neidhart. 1975. The behavior of mercury in the system water - fish. Bull. Environ. Contamin. Toxicol. 14:699-704.

At a mercury concentration of 1 mg/1, CH_3HgCl was taken up by fish 4X faster than $Hg(NO_3)_2$ due to greater lipid solubility of organic Hg. In the presence of complexing agents (10^{-7} mol/ml concentration), accumulation rates decreased due to a screening effect by complexing groups which allows only free Hg to enter cells. Tests using CH_3HgCl solutions of 0.1, 1, 5, 10, and 20 mg Hg/l produced higher accumulation (185, 1200, 4000, 9500, 17600 mg/kg, respectively, after 10 days) and greater accumulation rates (17.4, 113, 400, 950, 1760 mg/kg·d, respectively) as Hg concentration increased. Release of accumulated inorganic Hg occurs in a 2-step mechanism with a rapid first step (T 1/2 = 4.2 d) and slow second step (T 1/2 = 67.7 d). Accumulated organic Hg occurs in one slow step with a half life of 69 days. These results indicate that inorganic Hg is released 17X faster than incorporated CH_3HgCl, and that accumulated inorganic Hg is methylated in fish, then released in an identical manner as CH_3HgCl.

1792. Krasnov, E.V. and L.A. Pozdnyakova. 1975. Calcium-magnesium ratios in the calcite of the shells of marine mollusks as a criterion of specific and nonspecific reactions. Doklady Biol. Sci. Proc. Acad. Sci. USSR 220:18-19.

Ca/Mg ratio of shells varied periodically with distance from apex with limits of 110 to 470 for *Mizuhopecten yessoensis* and *Swiftopecten swifti* and 100 to 390 for *Chlamys nipponensis*. Ca/Mg ratios of shells showed bimodal frequencies with maximal peaks of 150, 200, and 260 for *C. nipponensis*, *M. yessoensis*, and *S. swifti*, respectively, and a secondary nonspecific peak of 280 to 330. Paleoecological implications are discussed.

1793. Krinsley, D. 1960. Trace elements in the tests of planktonic foraminifera. Micropaleontology 6(3):297-300.

Planktonic foraminifera tests from Atlantic cores contained 12 to 82 mg/kg of MnO, 310 to 600 mg/kg of TiO_2, 2700 to 6400 mg/kg of Al_2O_3, 1700 to 3700 mg/kg of MgO, 1100 to 2100 mg/kg of SrO, 10 to 38 mg/kg of CuO and 20 to 30 mg/kg of NiO. Manganese concentrations in planktonic foraminiferal tests appear to be related to location and probably time. Copper is relatively constant with respect to geographic location, with no apparent species effect. Sedimentary Mg is probably superimposed on biogenic Mg in foraminiferal tests. Sr is relatively stable from one core to another and is biogenic. Al and Ti are probably sediment contaminants; little information is available on Ni.

1794. Krinsley, D. and R. Bieri. 1959. Changes in the chemical composition of pteropod shells after deposition on the sea floor. Jour. Paleontology 33:682-684.

Modern planktonic pteropod shells contained metal levels, in mg/kg, of 3 to 8 for Al, <8 to 20 for Cu, 110 to 360 for Mg, 950 to 1400 for Sr and 2 to 15 for Mn. Higher concentrations of Al, Mn and Mg observed in shells from sediment cores apparently result from uptake after deposition. Both Cu and Sr levels were similar in planktonic and core samples.

1795. Kuhnert, P.M., B.R. Kuhnert, and R.B. Stokes. 1976. The effect of *in vivo* chromium exposure on Na/K- and Mg-ATPase activity in several tissues of the rainbow trout (*Salmo gairdneri*). Bull. Environ. Contamin. Toxicol. 15:383-390.

After low-level chromium exposure of 2.5 mg Cr^{+6}/l for 48 hrs, the mean tissue Cr levels in mg/kg wet wt increased from 0.22 to 2.16 in kidney, 0.18 to 0.58 in intestine, 0.11 to 0.54 in liver and 0.16 to 2.14 in gill. Sodium/potassium activated ATPase activity decreased after exposure for 48 hrs to Cr^{+6} in all tissues except gills. Kidney was the only tissue showing a significant decrease in Na/K-ATPase activity with 62% inhibition. A 50% reduction of intestinal Na/K-ATPase was observed, but this was not statistically significant at the 0.05 level. Changes noted in gill and liver were small and not significant. Mg-ATPase activity was unaffected by accumulation of Cr in tissue.

1796. Kulikov, N.V., V.G. Kulikova and S.A. Lyubimova. 1972. The movement of strontium-90 and cesium-137 along with fish eggs during spawning season. Soviet Jour. Ecol. 2(4):296-299.

Radioactivity levels per kg wet wt in gravid female tench *Tinca tinca*, and gravid female pike *Esox lucius*, minus stomachs and intestines, were 0.21 X 10^{-9} and 0.24 X 10^{-9} μ Ci for Sr-90, and 1.17 X 10^{-9} and 3.63 X 10^{-9} μ Ci for Cs-137. For selected stable cations these were 2.34 and 2.81 g for K, 4.55 and 6.33 g for Ca, and 2.13 and 8.21 g for Mg. Comparison of metal ratios of eggs to those of parent gave selectivity coefficients for tench and pike, respectively, of 15.9 and 4.0 for Sr-90:Ca, 0.3 and 0.3 for Sr-90:Mg, 75.4 and 14.8 for Mg:Ca, and 0.3 and 0.6 for Cs-137:K.

1797. Kustin, K., K.V. Ladd and G.C. McLeod. 1975. Site and rate of vanadium assimilation in the tunicate *Ciona intestinalis*. Jour. Gen. Physiol. 65:315-328.

Tunicates were reared in filtered seawater containing about 3.2 ug V/1. Using radioactive V-48 it was determined that vanadium is not transported from seawater into the tunicate body via the tunic. Site of V assimilation lies in the alimentary tract, with stomach and gut containing 510 and 257 mg/kg, respectively; other body parts contained between 11 and 68 mg/kg. Rate of radiovanadium exchange is first order with respect to V concentration over a 1000X increase in V^{+5} above natural levels in seawater, and shows no saturation. V accumulates in vanodocytes and forms a steady state concentration in membranes of branchial net and gastrointestinal tract; with the latter two possibly functioning as part of regulatory mechanism.

1798. Kustin, K., D.S. Levine, G.C. McLeod and W.A. Curby. 1976. The blood of Ascidia nigra: blood cell frequency distribution, morphology, and the distribution and valence of vanadium in living blood cells. Biol. Bull. 150:426-441.

Whole blood of ascidian A. nigra contained 51 mg V/1, present partially as V^{3+}. Green globular blood cells were primary V-bearers. V occurred in all 5 layers of centrifugated blood cells. Authors suggest that V may be present in more than one type of blood cell.

1799. Kwapulinski, J., A. Buszman and G. Kwapulinska. 1976. A model of the cumulation of ^{137}Cs in the carp (Cyprinus carpio L.). Acta Hydrobiol. 18:183-192.

An equation is presented to account for influence of Cs-137 in bottom sediments and from global fallout on Cs-137 content of carp; results were comparable with published data on trout. Cs-137 content in carp fry and second-year fish was weight dependent, with older fish containing nearly 2X levels of fry.

1800. Laarman, P.W., W.A. Willford, and J.R. Olson. 1976. Retention of mercury in muscle of yellow perch (Perca flavescens) and rock bass (Ambloplites rupestris). Trans. Amer. Fish. Soc. 105:296-300.

Mercury-contaminated perch and bass were collected from Lake St. Clair and stocked in two ponds. Twenty-six months later, mean concentrations of total mercury in fillets had declined from 0.97 to 0.46 mg/kg in perch, and from 0.94 to 0.39 mg/kg in bass; mean weight of the fish increased from 101 to 190 g in yellow perch and from 144 to 408 g in rock bass, during the same period. Reduction in mercury concentrations was attributable to dilution by growth. Slight discrepancies between theoretical and observed reduction of mercury concentrations suggest an initial redistribution of residues from other tissues to the muscle and a continued incorporation of background amounts of mercury during growth.

1801. Laevastu, T. and T.G. Thompson. 1956. The determination and occurrence of nickel in seawater, marine organisms, and sediments. Jour. du Conseil 21:125-143.

Marine plankton samples from Puget Sound, Wash., contained nickel levels ranging from 5.5 mg/kg dry wt (primarily diatoms) to 31 mg/kg dry wt (primarily copepods). Surface plankton showed concentration of Ni 2X that of deeper samples. Ni levels in fish muscle ranged from 0.32 to 1.70 mg/kg dry wt. Razor clam Siliqua patula, contained 0.74 mg Ni/kg dry flesh. Calcareous skeletons of marine animals contained from 0.31 to 0.46 mg Ni/kg. Water and sediments were also examined.

1802. Lahlou, B. and W.H. Sawyer. 1969. Sodium exchanges in the toad fish, Opsanus tau, a euryhaline aglomerular teleost. Amer. Jour. Physiol. 216(5):1273-1278.

Rate constants for Na turnover and total Na outflux rate in toadfish were 15.6% and 805 μEq/hr per 100 g. Upon transfer to freshwater, Na outflux dropped by 90% immediately and then continued to decrease for several days. Fish kept 4 to 11 days in freshwater remained in negative Na balance. Euryhalinity of toadfish may be explained in part by ability to reduce Na outflux instantaneously by an "exchange diffusion," followed by a further slow reduction on transfer to freshwater.

1803. Lake, P.S. and V.J. Thorp. 1974. The gill lamellae of the shrimp Paratya tasmaniensis (Atyidae: Crustacea). Normal ultra structure and changes with low levels of cadmium. Eighth Int. Cong. Electron Microsc., Canberra, Australia, Vol. II: 448-449.

Paratya exposed for 96 hrs to 0.03 and 0.05 mg/l of cadmium (about one-tenth of the LC-50 (96 hr) level) exhibited accumulation of granules (mean diameter of 470 A°) in some mitochondria, mitochondrial degeneration, dilation of intercellular spaces, and a dilation of rough endoplasmic reticular membranes. Effects were not as pronounced in thin regions of cytoplasm or in other cell types.

1804. Landé, S.P. and S.I. Guttman. 1973. The effects of copper sulfate on growth and mortality rate of *Rana pipiens* tadpoles. Herpetologica 29:22-27.

Fertilized *Rana pipiens* eggs were not affected by copper concentrations ranging from 0.04 to 1.56 mg/l Cu (as $CuSO_4$). Tadpole LC-50 (72 h) was 0.15 mg/l Cu; LC-100 (72 h) was greater than 0.16 mg/l Cu and less than 1.25 mg/l Cu. Total mortality occurred within 4 days after hatching in concentrations of 0.31, 0.62 and 1.56 mg/l Cu. Weights of tadpoles grown in 0.06 and 0.16 mg/l Cu were lower than controls and those grown in 0.04 and 0.05 mg/l Cu. It appeared that as the size of the tadpole increased, the survival time increased such that the correlation coefficient (r) was +0.74 (P=>0.05).

1805. Lansing, A.I. 1942. Some effects of hydrogen ion concentration, total salt concentration, calcium and citrate on longevity and fecundity of the rotifer. Jour. Exp. Zool. 91:195-211.

Experiments were conducted on 3 species of freshwater rotifers, *Euchlanis triquetra*, *Rotifer vulgaris*, and *Proales* sp. Fertility and longevity of *Euchlanis* were increased in alkaline solutions compared with solutions of pH 6.0 and 7.0. Solutions of pH 4.0 and 5.0 were toxic. *Rotifer vulgaris* deposited more eggs/d and had a longer life span at a total salt concentration of 0.02% than 0.04%; *Proales* had a shorter life span but deposited 2X number of eggs at 0.02% than 0.04%. Fertility of *Proales* was not appreciably altered in low and high calcium concentrations; but life span was markedly increased in low Ca solutions. Periodic immersion of *Proales* in sodium citrate results in approximately a 50% increase in life span and an increase in average number of eggs laid per day.

1806. Larimer, J.L. and A.F. Riggs. 1964. Properties of hemocyanins - I. The effect of calcium ions on the oxygen equilibrium of crayfish hemocyanin. Comp. Biochem. Physiol. 13:35-46.

Oxygen affinity of hemocyanin from crayfish *Procambarus simulans*, is greatly decreased by dialysis between pH 6.5 and 8.0. This effect is further reduced by addition of Ca^{2+} at 0.4 g/l, or Mg^{2+} at 1.28 g/l. Since Ca^{2+} concentration in crayfish blood changes during molting, it is suggested that Ca^{2+} modifies the O_2 transport function of hemocyanin by changing degree of aggregation.

1807. LaRock, P.A. and H.L. Ehrlich. 1975. Observations of bacterial microcolonies on the surface of ferromanganese nodules from

Blake Plateau by scanning electron microscopy. Microbial Ecol. 2:84-96.

Microcolonies of rod- and coccus-shaped bacteria were attached by slime to the surface of ferromanganese nodules.

1808. Larsson, A. 1975. Some biochemical effects of cadmium on fish. *In* Koeman, J.H. and J.J.T.W.A. Strik (eds.). Sublethal *effects* of toxic chemicals on aquatic animals. Elsevier Sci. Publ. Co., Amsterdam: 3-13.

Exposure for 11 to 15 days to subacute levels of cadmium (1-10 mg Cd^{2+}/l) caused blood anemia and hyperglycemia in teleosts. After exposure for 15 days to 10 mg Cd^{2+}/l, flounders (*Pleuronectes flesus* L.) exhibited a decrease in hematocrit from 21% to 17%, a decrease in hemoglobin, and an increase in blood glucose levels by 75%. Long-term exposure of 4 and 9 weeks to sublethal cadmium levels of 0.005 to 0.500 mg Cd^{2+}/l had similar effects. After 9 weeks exposure to 0.005 mg Cd/l, hematocrit of *P. flesus* dropped from 22.1% to 16.0%, hemoglobin values decreased from 6.1 to 4.4 g/100 ml, and blood glucose levels rose from 24.7 to 29.2 mg/100 ml. In addition, cadmium seriously affected blood plasma levels of potassium, calcium, magnesium and inorganic phosphate. Observed effects of cadmium in fish are discussed in relation to cadmium toxicosis in mammals, man included.

1809. Laurie, R.D. and J.R.E. Jones. 1938. The faunistic recovery of a lead-polluted river in North Cardiganshire Wales. Jour. Animal Ecol. (Britain) 7:272-286.

In the Lower Rheidol River, a total of 14 species of arthropods were present between 1919 and 1921, during which Pb concentrations were 0.2 to 0.5 mg/l water. Lower Pb contents of <0.02 mg/l, except for occasional peaks of 0.4 mg/l, were accompanied by increased species counts of 29 in 1922 and 103 in 1932. Sticklebacks *Gasterosteus aculeatus*, which is one of the most sensitive species to lead in the Rheidol, died after 14 days exposure to 0.1 mg Pb/l water, which was maximum recorded Pb concentration in the Lower Rheidol for several years prior to 1938. At the present concentration of 0.02 mg Pb/l, fish could survive indefinitely, suggesting that Pb concentrations no longer endanger fish. Trout *Salmo trutta* were abundant from 1932. Authors concluded that river fauna had recovered fully from previous Pb pollution.

1810. Lawrence, J.M. 1956. Preliminary results on the use of potassium permanganate to counteract the effects of rotenone on fish. Prog. Fish-Cult. 18(1):15-21.

Potassium permanganate counteracts toxic action of rotenone to fish by oxidizing rotenone to a nontoxic form. When tap water was used in aquaria, 0.05 mg/l rotenone was effectively detoxified by 2 mg/l $KMnO_4$ over the temperature range 7 to 27 C. In field trials on ponds and streams, concentrations of $KMnO_4$ ranging from 2.0 to 2.5 mg/l successfully detoxified 0.05 mg/l rotenone. In aquaria at a temperature of 27 C, LC-100 (minimum concentration of $KMnO_4$ that killed all fish) for bluegills was 3 mg/l; for largemouth bass this was 4 mg/l, and for fathead minnows 5 mg/l. At 14.5 C, LC-100 for bluegills and largemouth bass was approximately 5 mg/l. Use of potassium permanganate apparently had no harmful effects on waters treated but owing to its fungicidal action may have beneficial effects on any fish present or those added immediately to such treated waters.

1811. Lay, B.A. 1971. Applications for potassium permanganate in fish culture. Trans. Amer. Fish. Soc. 100(4):813-816.

By oxidizing organic and inorganic materials which consume oxygen, potassium permanganate in amounts of 2-6 mg/l indirectly increases soluble oxygen thereby preventing fish kills in culture ponds. Diseases including fungi, some protozoans, parasitic copepods, and monogenetic trematodes, have been effectively controlled by $KMnO_4$. At concentrations of 2.0-2.5 mg/l, $KMnO_4$ will neutralize toxicity of 0.05 mg/l rotenone, and 3.0 mg/l may detoxify 0.005 mg/l antimycin. Previous toxicity studies have determined that LC-0 (maximum concentration where no fish killed) for catfish at 25 C is 9.1 mg/l for 1 hr and 3.2 mg/l for 24 hr. The LC-100 (all fish killed) for guppies is 20 mg/l; for bluegills, walleyes, and sauger, the LC-100 was 3 mg/l; for largemouth bass, 4 mg/l; fathead minnow, 5 mg/l; and goldfish, 6 mg/l. $KMnO_4$ may effectively control nuisance algae without harming fish.

1812. Lebedeva, M.N. and A.I. Shtevneva. 1975. Heterotrophic microflora fouling and its influence upon the corrosion of metals in the oxygen and hydrosulphuric zones in the Black Sea. Okeanology 15(4):649-654. (In Russian, English summary)

An aluminum alloy (Amg-61) is more resistant to bacterial fouling than steel (St. 3, Yu. 3). Fouling by heterotrophic microflora in an oxygen-rich zone is 3 to 15X that in hydrosulphuric zone, with maximum rates in autumn and minimum rates in winter.

1813. LeBlanc, P.J. and A.L. Jackson. 1973. Arsenic in marine fish and invertebrates. Marine Poll. Bull. 4(6):88-90.

Background levels of arsenic in organisms near a proposed mine site on the Pacific coast of Canada were determined. The highest concentrations of arsenic (in mg/kg wet wt) in muscle or soft parts of invertebrates was: 37.8 in *Cancer magister* (crab); 15.6 in *Macoma* sp. and *Clinocardium* sp. (clams); 5.9 in *Hexanchus griseus* (shark); 5.6 in *Squalus acanthias* (dogfish); 16.2 in *Raja* sp. (skate); 10.3 in *Hydrolagus colliei* (ratfish); <0.4 in *Oncorhyncus* sp. (salmon); <0.4 in *Salmo gairdneri* (steelhead); 0.3 in *Olphiodon elongatus* (cod); 2.6 in *Sebastes* sp. (rockfish); 0.8 in *Hexagrammos* sp. (greenling); and 11.5 in *Psettichthys melanostictus* and *Parophrys vetulus* (sole). Author concludes that arsenic accumulates in marine fishes and invertebrates and may be a micronutrient.

1814. Lee, G.F. and W. Wilson. 1974. Studies on the Ca, Mg, and Sr content of freshwater clamshells. Wisconsin Acad. Sciences, Arts and Letters 62:173-180.

Different laminar layers of *Lampsilis siliquoidea rosacea* shell from 3 Wisconsin lakes had concentrations of 371-451 g Ca/kg, 33-216 mg Sr/kg, and 27-102 mg Mg/kg. Ratios of Sr/Ca extended from 61 x 10^{-6} to 258 x 10^{-6}; for Mg/Ca ratios this was 115 x 10^{-6} to 431 x 10^{-6}. In 3 different Wisconsin lakes shells contained 413 g Ca/kg of shell, and exhibited slightly different Sr/Ca and Mg/Ca ratios; this could be explained by differences in water content of Ca, Mg, and Sr.

1815. Lemée, J.C., J. Ancellin, and A. Vilquin. 1970. Contaminations de crevettes roses (*Leander serratus* Pen.) au moyen du caesium 137 par voie alimentaire. Radioprotection 6(2):133-142. (English abstract)

Shrimps were fed mussels contaminated with Cs-137. A sharp rise in contamination was noticed after each meal followed by partial decontamination. Residual contamination was in the range of 15% of diet activity. A comparison between the importance of contamination from either diet or environment showed that the latter was higher.

1816. Lett, P.F., G.J. Farmer and F.W.H. Beamish. 1976. Effect of copper on some aspects of the bioenergetics of rainbow trout (*Salmo gairdneri*). Jour. Fish. Res. Bd. Canada 33:1335-1342.

Initial response of trout exposed for 40 days to 0.0 to 0.3 mg Cu/l (the LC-50 value at 96 hr ranged from 0.25 to 0.68 mg/l) was cessation of feeding. Thereafter, food intake rates returned to control levels. Growth rate of trout exposed to 0.075 to 0.225 mg Cu/l was initially depressed but approached control values after 40 days. During this period, the lipid, protein, and moisture of fish exposed to Cu did not change. Initial growth retardation was not attributable to interference with digestion.

1817. Lewin, J. and C.H. Chen. 1976. Effects of boron deficiency on the chemical composition of a marine diatom. Jour. Exp. Botany 27:916-921.

Cells of the marine pennate diatom Cylindrotheca fusiformis, multiplied in complete nutrient medium (containing 0.5 mg B/l) with a generation time of 11 hr. In a boron-deficient culture medium (0.02 mg B/l), generation time was 90 hr. Comparison of chemical compositions of logarithmically growing cells of each culture condition showed that in boron deficient cells, the concentration of protein, carbohydrates, and RNA was depressed below control cells, that DNA showed no change, and that lipids, phenolic compounds, and unaccounted-for organic fractions all increased.

1818. Lewis, G.B. and A.H. Seymour. 1965. Distribution of zinc-65 in plankton from offshore waters of Washington and Oregon, 1961-1963. Ocean Science Ocean Eng. 1965:956-964.

Distribution of zinc-65 in unsorted plankton consisting of crustaceans, ctenophores and phytoplankton and collected within 220 km of the Columbia River mouth, conformed to the general pattern of horizontal distribution of Columbia River water. Zinc-65 was detected in 202 of 238 samples. The maximum value in picocuries per gram dry wt was 1,300; arithmetic mean was 132; geometric mean 47. Zinc-65 values showed seasonal changes and a close relationship with zinc-65 in river water.

1819. Lewis, M.L. 1976. Effects of low concentrations of manganous sulfate on eggs and fry of rainbow trout. Prog. Fish-Cult. 38:63-65.

Groups of trout eggs exposed to 0, 1, 5, and 10 mg/l of manganous sulfate for 29 days exhibited 7, 12, 22 and 30% mortality, respectively. Most sensitive periods were at day 7 when eye pigments appeared, and at hatching (day 29). In avoidance tests, fry were unable to detect high (10 mg/l) levels of manganous sulfate.

1820. Lewis, S.D. and W.M. Lewis. 1971. The effect of zinc and copper on the osmolality of blood serum of the channel catfish, *Ictalurus punctatus* Rafinesque, and golden shiner, *Notemigonus crysoleucas* Mitchill. Trans. Amer. Fish. Soc. 100(4):639-643.

Exposure of fish to 2.5 and 5 mg/l Cu or 8.12 and 30 mg/l Zn produced reductions in blood serum osmolality. Mortality occurred when osmolality dropped below 230 mOsm (5.0 mg/l Cu for golden shiner, 2.5 mg/l Cu and 12 to 30 mg/l Zn for channel catfish). With Zn, osmotic drop is principally related to damage to head and gill areas of fish. In presence of excess calcium there is no precipitation of mucus, no respiratory distress, and no mortality. Addition of NaCl to water with Cu or Zn also prevented distress symptoms and mortality, but caused osmolality in fish to increase over levels of NaCl solution alone. Authors suggest that heavy metals affect head or gill area of fish with a subsequent drop in salt concentration of blood.

1821. Lindahl, P.E. and E. Schwanbom. 1971. A method for the detection and quantitative estimation of sublethal poisoning in living fish. Oikos 22:210-214.

Swimming ability of roach *Leuciscus rutilus*, in a rotary flowing water channel was used to evaluate sublethal poisoning. On acceleration of the device from zero to the maximum number of revolutions per minute (40 to 60 r.p.m.) the "critical r.p.m." is that which the fish is unable to compensate for torque and forced to rotate. Exposure to about 10 μg/l of methylmercuric hydroxide (MMH) significantly decreases the critical r.p.m. Decreases in critical r.p.m. of fish exposed to MMH was linearly correlated to mercury residues per unit wet wt of muscle.

1822. Lindberg, E. and C. Harriss. 1974. Mercury enrichment in estuarine plant detritus. Marine Poll. Bull. 5:93-95.

Relative mercury concentrations are enriched by a factor of 10 in decomposition products of the red mangrove, *Rhizophora mangle*, compared with living plant tissue. The mercury content of mangrove detritus is 3 to 30 times higher than values reported for marine phytoplankton. It was concluded that detritus formation represents a natural mechanism for mercury enrichment in estuarine food chains.

1823. Lloyd, R. and D.W.M. Herbert. 1962. The effect of the environment on the toxicity of poisons to fish. Jour. Inst. Public Health Eng. 61:132-145.

Toxicities of monochloramine (as Cl), un-ionized ammonia, copper sulphate, zinc sulphate, and anionic detergents are discussed as functions of chemical and physical properties of the water. Increasing temperature decreases survival times, perhaps due to metabolic rate increases, but relation between survival time and temperature is not the same for all fish species. For zinc, there is a threshold concentration at which there is no temperature effect. Toxicity of metal salts may be reduced in alkaline water by formation of an insoluble basic salt, however, susceptibility of fish to ions remaining in solution can be reduced by increasing Ca content. For example, fish acclimated to different total water hardness levels then exposed to dilutions of Zn, Pb, and Cu salts showed a linear relation between the logarithm of threshold concentration and logarithm of total hardness. Exposing fish to graded concentrations of Pb, Cu, or Zn sulphates at different dissolved oxygen levels, none of which were low enough to be lethal, showed that toxicities increase markedly with decreasing dissolved O_2 levels. Authors suggest that this increase in toxicity may be due to increased water flow over gills as O_2 content decreases. Since gills are site of action or absorption for most toxins, this increased water flow brings more poison into contact with fish. When poisons were present in mixtures, it was found that the threshold for the mixture was reached when the sum of the fractions reached unity.

1824. Lock, R.A.C. 1975. Uptake of methylmercury by aquatic organisms from water and food. *In* Koeman, J.H. and J.J.T.W.A. Strik (eds.). Sublethal effects of toxic chemicals on aquatic animals. Elsevier Sci. Publ. Co., Amsterdam: 61-79.

Accumulation and effects of high (1-40 mg/l) sublethal concentrations of methylmercury to freshwater green alga *Chlamydomonas reinhardtii*, cladoceran *Daphnia pulex* , and rainbow trout *Salmo gairdneri* were determined. Exposure to increased methylmercury concentrations resulted in a lengthened lag phase in algal cultures, with mean generation times of 44, 48, 51 and 61 hrs for cultures grown at 0, 1, 5, and 10 mg Hg/l respectively. At 20 mg Hg/l, growth was severly retarded; at 40 mg Hg/l cells died. Methylmercury levels in living and killed *C. reinhardtii* were the same during the first 10 hrs, suggesting that initial uptake is passive adsorption rather than active uptake. In daphnia and trout, methylmercury uptake rate was higher from medium than food, but percentage uptake of Hg was 5 to 10X higher from food. In both species, uptake of Hg at concentrations below 1.0 mg Hg/l was linearly related to methylmercury concentrations in medium. At higher levels, however, uptake rate decreased. Author suggests that increased mucus production at respiratory surfaces and gut epithelium may limit Hg uptake. Since dissolved methylmercury in water is present in concentrations below 1 mg Hg/l and cannot account for levels found in higher trophic level organisms, and since practically all methylmercury is complexed to organic matter, it was concluded that organisms accumulate most of their methylmercury burden from food.

1825. Lockwood, A.P.M. and C.B.E. Inman. 1975. Diuresis in the amphipod, Gammarus duebeni induced by methylmercury, D.D.T., lindane and fenithrothion. Comp. Biochem. Physiol. 52C: 75-80.

Effect of lethal and sublethal concentrations of methylmercury and other substances on rate of urine production in marine amphipods was examined. In 100% seawater, methylmercury initiated diuresis at 56 μg/l, which is less than 30% of the LC-50 (96 hr) value. Water permeability, total body water, blood K levels and urine/blood ratio for (Cr-51)-EDTA remained unchanged in amphipods exposed to 100 μg/l methylmercuric chloride, a concentration which induces diuresis. Sodium uptake increased at this concentration. Mechanisms of toxicant-induced diuresis and its ecological significance are discussed.

1826. Lorz, H.W. and B.P. McPherson. 1976. Effects of copper or zinc in fresh water on the adaptation to seawater and ATPase activity and the effects of copper on migratory disposition of coho salmon (Oncorhynchus kisutch). Jour. Fish. Res. Bd. Canada 33:2023-2030.

Acute toxicity bioassays were conducted at water alkalinity of 68 to 78, water hardness of 89 to 99 mg/l as $CaCO_3$, and at 10 to 12 C. The LC-50 (96 hr) value for Cu, as $CuCl_2$, for yearling salmon decreased from 74 μg/l in November to 60 μg/l in May as fish became smolts. The LC-50 (96 hr) value for Zn, as $ZnCl_2$, for yearling coho in April was 4600 μg/l.

Exposures for 144 hr to sublethal concentrations of Zn in freshwater had little effect on enzyme activity of Na^+, K^+-activated ATPase in gill microsomes or on survival of fish transferred to seawater. Acute and chronic exposures up to 4128 hr of yearling coho salmon to 5 to 30 μg Cu/l in freshwater had deleterious effects on gill ATPase activity, survival in seawater, and on downstream migration after fish were placed in a natural stream. More severe effects were produced in chronic exposures than in 144 hr exposures on downstream migration and survival in seawater, but not on gill ATPase. Effects of Cu began to occur within 24 to 72 hr and were often maximized within 120 to 144 hr of exposure.

1827. Lovelace, F.E. and H.A. Podoliak. 1952. Absorption of radioactive calcium by brook trout. Prog. Fish-Cult. 14(4):154-158.

Trout held in water containing 5000 c/m/ml of radioactive calcium for 24 hr had radioactivity values, in μ Ci/g wet tissue of 0.0338 for gills, 0.00942 for gastro-intestinal tract, and 0.01820 for body residue. It was concluded that Ca absorption by trout from water was primarily through gills.

1828. Lowman, F.G., R.F. Palumbo and D.J. South. 1957. The occurrence and distribution of radioactive non-fission products in plants and animals of the Pacific Proving Ground. Univ. Washington Rept. UWFL-51:61 pp. Available from Tech. Inf. Ser. Ext., Oak Ridge, Tenn.

Isotopes contributing to total radioactivity in clam kidney collected from Eniwetok Atoll in 1956 as % of radioactive output were: Ru-106-Rh-106 0.7; Zr-95-Nb-95 0.2; Y-91 2.6; Mn-54 2.2; Fe-55 73.5; Fe-59 0.2; Co-57 9.6; Co-58 9.2; and Co-68 1.8. Isotopes contributing to radioactivity of various fish liver samples were Mn-54 (0.5 to 6.4%), Fe-55 (15.2 to 95.3%), Fe-59 (0 to 0.1%), Co-57 (0.2 to 8.1%), Co-58 (0 to 0.9%), Co-60 (0.8 to 7.2%), Zn-65 (3.1 to 58.1%). Mn-54, Zn-65, Fe-59, Co-60, Co-58 and Co-57 were not found in 6 species of algae sampled during the same year. Zn-65 was the predominant radioisotope in liver, muscle, gut, lung, liver and kidney of terns. Authors conclude that non-fission radioisotopes Mn-54, Fe-55, Fe-59, Co-57, Co-58, Co-60 and Zn-65 account for almost all radioactivity in marine animals.

1829. Lucu, C., O. Jelisavcic, S. Lucic and P. Strohal. 1969. Interactions of ^{233}Pa with tissues of Mytilus galloprovincialis and Carcinus mediterraneus. Marine Biology 2:103-104.

Contamination factors (c.f.) in mussels after 20 days in Pa-233, were 2500 for byssus, 150 for shell, 100 to 200 for digestive tract, ∿60 for gills, ∿15 for reproductive system and ∿10 for muscle. In the crab, c.f.'s were 2500 in gills, <200 in skeleton and digestive tract and 5 to 20 in reproductive system and muscle; hemolymph was nearly uncontaminated. High contamination of digestive tract and gills was directly related to feeding and filtration, respectively. High values in byssus, skeleton, gills and digestive tract were due to surface adsorption. Complexing by EDTA had no effect on degree of contamination of either mussels or crabs.

1830. Lunde, G. 1967. Activation analysis of bromine, iodine, and arsenic in oils from fishes, whales, phyto- and zooplankton of marine and limnetic biotopes. Int. Revue ges. Hydrobiol. 52(2):265-279.

The method developed for anlayzing Br, I, and As in oils was based on neutron activation and measurement of induced radioactivity by a γ-spectrometer without any chemical treatment of oils. Results for freshwater fish gave concentrations (in mg/kg) of 0.3 to 7.7 Br, <0.1 to 0.9 As, and 0.1 to 9.1 I. Saltwater fish contained 2.0 to 47.0 Br, 0.5 to 15.5 As, and 2.7 I. Oil from cod (*Gadus morrhua*) contained levels of 3.7 to 59.6 Br, 0.7 to 26.0 As, and 5.4 to 60.4 I. Oil from herring (*Clupea harengus*) had 0.7 to 24.0 Br, 3.1 to 14.3 As, and 1.2 to 5.1 I. Whale oil contained 0.5 to 5.6 Br and 0.6 to 2.8 As. Concentrations of 20 to 150 mg/kg Br, but no As or I were found in freshwater plankton (rotifers, diatoms, dinoflagellates, blue-green algae), whereas saltwater plankton contained 10,900 to 15,870 mg/kg Br and no As. Values indicate that nutrition is an important factor. Limnetic organisms generally contained less Br, I, and As than marine organisms; fishes from coastal areas and fiords had higher Br content in relation to As than fishes from the open sea; and Br:As ratio was higher in liver than in tissues. Results also support earlier assumptions that I and As are present as organic compounds, and suggest that Br is also. No sign of Br, I, or As was observed in oil samples extracted from terrestrial plants and animals.

1831. Lunde, G. 1968. Activation analysis of trace elements in fishmeal. Jour. Sci. Fd. Agric. 19:432-434.

Fishmeals produced from herring *Clupea harengus*, mackerel *Scomber scomber*, capelin *Mallotus villosus*, and Norway pout *Gadus esmarki* were analyzed by neutron activation for mercury, bromine, arsenic, selenium, antimony, copper, cobalt, iron, zinc, molybdenum and tungsten. The distribution of these elements in the solid and aqueous phases in boiled fish used as raw material for fishmeal was also studied.

Highest values recorded, in mg/kg, for press cake, N liquor, and factory-produced fishmeal, were as follows:

	press cake	N liquor	fishmeal
Se	2.7	15.1	5.3
As	4.5	15.2	19.1
Sb	0.061	<0.01	0.20
Co	0.17	0.28	0.82
Cu	11.2	17.2	4.1
Zn	86.0	6.7	180
Fe	23.0	4.4	106

Hg	0.41	<0.01	0.40
Mo	0.26	<0.05	0.16
W	<0.005	<0.005	0.030

1832. Lunde, G. 1968. Analysis of arsenic in marine oils by neutron activation. Evidence of arseno organic compounds. Jour. Amer. Oil Chem. Soc. 45:331-332.

The arsenic content of phospholipid fractions separated from codliver oil (Gadus morrhua) and herring oil (Clupea harengus) was analyzed by means of neutron activation. The fractions were separated on a silicic acid column by chloroform/methanol mixtures as eluting agents. Results indicate that the arsenic appears as arseno organic compounds. Two such compounds were evident in herring oil. The arsenic content in one fraction was about 3000 mg/kg. Author suggests that it is the fish itself or other organisms contained in the food intake of the fish which synthesizes these arseno organic compounds. The arsenic in seawater (about 3 ug/l) appears mainly as the inorganic anion.

1833. Lunde, G. 1969. Water soluble arseno-organic compounds in marine fishes. Nature 224:186-187.

When raw fish is boiled, arsenic is enriched in the water soluble phase (N-liquor). Using radioactive ion exchange, it was determined that this As is present chiefly as one or more arseno-organic compounds in which organic As does not exchange with inorganic As. Arsenic levels in mg/kg dry wt in N-liquor ranged in herring Clupeus harengus from 5 to 21, in mackerel Scomber scomber it was 3.1, and in capelin Mallotus villosus from 3 to 8.

1834. Lunde, G. 1970. Analysis of arsenic and selenium in marine raw materials. Jour. Sci. Food Agric. 21:242-247.

Arsenic and selenium were determined in various marine organisms: cod Gadus morhua, herring Clupea harengus, mackerel Scomber scomber, Norway haddock Sebastes marinus, lobster Homarus vulgaris, mussel Mytilus edulis, clam Pecten maximum, oyster Ostrea edulis, squid Ommastrephes sagittatus, and whale Balaenoptera physalus. The analyses were performed on both the raw material and the water-soluble phase after boiling (the N liquor). An enrichment of arsenic is observed in the N liquor, compared with the raw material. Results indicate that selenium is also enriched in the N liquor from fish, but not from invertebrates. Arsenic values, in mg/kg, in dehydrated raw material ranged from 0.36 (whale meat) to 11.6 (clam); for selenium these values were <0.5 (oyster, whole meat) to 8.4 (cod skin). For N liquor, arsenic values ranged from not detectable in various fish tissues to 37 mg/l for cod liver; for selenium, values ranged from not detectable to 4.5 mg/l for haddock fillets.

The N liquor and the water-soluble phase of the enzyme-hydrolyzed presscake (the water-insoluble phase after boiling) were fractionated by molecular gel filtration. Fractions from these elutions were analyzed for arsenic and selenium. Selenium was present in the fractions with a molecular weight above about 5000. Arsenic was connected with the lower molecular weight fractions, and may be present as more arseno-organic compounds.

1835. Lunde, G. 1970. Analysis of trace elements in seaweed. Jour. Sci. Food Agric. 21:416-418.

Trace element composition of algae collected from two different localities in Norway was determined by neutron activation and atomic absorption. One locale was characterized by a relatively strong influence of river water and industrial waste; the other locale was free from this type of contamination. For all species of algae regardless of collection locale the following values were observed in mg metal per kg dry wt: arsenic, 10-109; copper, 6-63; molybdenum, 0.3-5.8; manganese, 4-164; zinc, 53-520; cobalt, 0.1-5.2; antimony, 0.05-2.5; selenium, 0.04-0.24; and iron, 33-931. Considerable differences in content of trace elements were found between the Laminariaceae and Fucaceae. In one species of alga (Laminaria hyperborea) content of As, Sb, and Zn were higher in Feb-April than Sep-Nov. Marine algae, when compared to terrestrial plants, generally contained higher concentrations of Zn, Cu, and especially As.

1836. Lunde, G. 1972. The analysis of arsenic in the lipid phase from marine and limnetic algae. Acta Chem. Scand. 26(7): 2642-2644.

Arsenic, in mg/kg, in freshwater algae was: Chlorella pyrenoidosa 0.5; Oscillatoria rubescens 0.4 and 0.5; and Phaeodactylum tricornutum 4.8. For marine algae these were: Chlorella ovalis 0.7; Phaeodactylum tricornutum 3.6; and Skeletonema costatum 1.3. Algae were cultivated using enriched media containing 1-3 ug/l As. If this value is accepted, then the enrichment coefficient is approximately 200 to 5000.

1837. Lunde, G. 1972. Analysis of arsenic and bromine in marine and terrestrial oils. Jour. Amer. Oil Chem. Soc. 49:44-47.

Oils extracted from marine teleosts, molluscs, echinoderms, crustaceans, seaweeds, seagulls, and terrestrial birds, mammals, and plants were analyzed for arsenic and bromine content. Lipid-soluble bromine and arseno organic compounds are characteristic components of marine animal and plant oils. Bromine-containing compounds seem to be relatively stable, but the arseno-containing compounds are not. On saponification, some of the As and Br compounds were found in the fatty acid fraction while others appeared in the water soluble fraction. Arsenic values in oil ranged from 4.7 to 84 mg/kg for marine macrofauna, 5.7 to 221 for marine seaweeds, <0.2 for terrestrial birds, animals, and plants, and 0.6 to 13.2 mg/kg for seagulls (3 spp.).

1838. Lunde, G. 1973. Trace metal contents of fish meal and of the lipid phase extracted from fish meal. Jour. Sci. Food Agric. 24:413-419.

In fish meal produced industrially and in the laboratory from mackerel *Scomber scomber*, herring *Clupea harengus*, Norway pout *Boreogadus esmarkii*, and capelin *Mallotus villosus*, the following trace elements were determined: Cd, Zn, Pb, Cu, Fe, and Co; and, in the lipid phase extracted from the meals: Se, As, Br, Zn, Fe, and Cu. Levels of zinc, lead and iron are higher in the industrially produced meals (up to 639, 3.8 and 757 mg/kg, respectively) compared to those produced in the laboratory (up to 62, 0.52 and 64 mg/kg, respectively). Assuming that the zinc to cadmium ratio occurring naturally in seawater is about 100 to one, then results suggest that Zn seems to be enriched relative to Cd in the fish meal where ratios of 100 to 1000 were observed, with Zn ranging between 38-639 mg/kg and Cd ranging between 0.02-0.96 mg/kg. Other trace metals anlayzed in industrial fish meal were Cu (2.3-13.8 mg/kg) and Se (0.6-4.2 mg/kg). The ranges in concentrations (in mg/kg) of these elements from the lipid phase of factory produced fish meal are: As 4.6-23.2, Br 8.1-18.5, Se 0.07-3.3, P 1600-22,310, Zn 1.1-54, Fe 2.6-67, and Co <0.02-0.21; organic lipid-soluble selenium compounds do not decompose during the production of fish meal.

1839. Lunde, G. 1973. Separation and analysis of organic-bound and inorganic arsenic in marine organisms. Jour. Sci. Food Agric. 24:1021-1027.

A method for separation of stable arseno-organic compounds from inorganic arsenic and subsequent determination of both forms of As is described. Inorganic, organic, and total As values are given for shrimp *Pandalus borealis*, mussel *Mytilus edulis*, mackerel *Scomber scombrus*, haddock *Melanogrammus aeglefinus*, cod *Gadus morhua*, capelin *Mallotus villosus*, tunny *Thunnus thynnus*, coalfish *Pollachius virens*, herring *Clupea harengus*, defatted enzyme hydrolyzed cod liver *Gadus morhua*, seaweed *Laminaria hyperborea*, extract of herring, extract of coalfish, and herring meal. Inorganic As values ranged from 0.7 (extract of coalfish) to 3.2 mg/kg dry wt (herring); organic As ranged from 3.4 (herring) to 139 mg/kg dry (seaweed); and total As ranged from 4.2 (herring) to 142 mg/kg dry (seaweed).

1840. Lunde, G. 1973. The analysis of organically bound elements (As, Se, Br) and phosphorus in raw, refined, bleached and hydrogenated marine oils produced from fish of different quality. Jour. Amer. Oil Chem. 50:26-28.

When raw fish deteriorated during storage, selenium and phosphorus contents of oils increased (Se from $\sim$0.05 mg/l to >0.20 mg/l in 13 days), whereas bromine and arsenic contents remained constant. During refining, As and P disappear almost completely whereas Se content decreased by two-thirds. In the hydrogenation step Se disappears relatively rapidly (decreasing to <0.02 mg/l) and Br more slowly. Respective ranges of Se and As in fresh fish oils, in mg/l were: 0.02 to 0.09 (Se) and 5.3 to 6.5 (As) for herring; 0.05 (Se) and 4.6 to 5.2 (As) for mackerel; 0.09 (Se) and 9.1 (As) for capelin.

1841. Lunde, G. 1973. The synthesis of fat and water soluble arseno organic compounds in marine and limnetic algae. Acta Chem. Scand. 27(5):1586-1594.

Two green algae (*Chlorella ovalis* and *Chlorella pyrenoidosa*), one blue green (*Oscillatoria rubescence*) and two diatoms (*Phaeodactylum tricornutum* and *Skeletonema costatum*), grown in fresh or salt water or both, synthesize fat soluble and water soluble arseno organic compounds from inorganic As^{5+} or As^{3+}. At arsenic concentrations up to 100 ug/l, *P. tricornutum* and *C. ovalis* convert As to arseno organic compounds at rates inversely proportional to As concentration. Further increases (up to 1 to 10 mg As/l) lead to a constant arseno organic synthesis rate. Arsenic is accumulated by factors of 200 to 3000 in algae. Acid treatment converted different arsenolipids into a water soluble product apparently identical to an arseno organic compound isolated from fat-free algal material from field collections. Algae seem to be an important source of arseno organic compounds found in higher marine organisms.

1842. Lytle, T.F., J.S. Lytle, and P.L. Parker. 1973. A geochemical study of a marsh environment. Gulf Research Rep. 4(2): 214-232.

Marsh plants and sediments of Harbor Island, Texas, were analyzed for hydrocarbons and trace metals. For 14 species of marsh plants, metals in mg/kg dry wt ranged from 9 to 170 for Mn, 47 to 200 for Fe, 0.06 to 0.65 for Co, 0.2 to 2.6 for Ni, 1.0 to 9.4 for Cu, 3 to 50 for Zn, 0.3 to 2.5 for Mo, 0.07 to 0.74 for Cd, and 0.8 to 4.2 for Pb. In some cases marsh plants may serve as sources for trace metal enrichment in the sediments, and in other instances (Mo) as an active depleting agent.

1843. MacCarthy, J.J. and G.W. Patterson. 1974. Effects of cation levels of the nutrient medium on the biochemistry of *Chlorella* I. Concentration series. Plant Physiol. 54:129-132.

Effects of varying levels of Mg^{2+}, K^+ and Ca^{2+} from deficiency to toxicity levels on *Chlorella sorokiniana* were observed. At lowest level of 0.01 meq/l Mg^{2+}, growth rate was 4.7 doublings/day. Increasing the Mg^{2+} level increased growth rate to a maximum of about 8.6 doublings/day; this was maintained until toxic level of 200 meq/l was reached. The sufficiency value, or lowest concentration giving maximal growth, was 0.08 meq/l. Cellular levels of Mg^{2+}, K^+, total N, total fatty acids and unsaturated fatty acids were reduced under conditions of Mg^{2+} deficiency. As Mg^{2+} concentration was raised, level of each fraction increased and remained high until Mg^{2+} toxicity levels were reached. Saturated fatty acids were reduced by increasing Mg^{2+} concentration whereas total lipid levels were unaffected; cellular sufficiency level of Mg^{2+} was 0.29% of dry wt. At lowest K^+ level of 0.003 meq/l, growth rate was 4.8 doublings/day; increasing K^+ levels were accompanied by increasing growth rates until K^+ sufficiency level of 0.10 meq/l was attained. At K^+ toxicity of 499 meq/l, growth rate declined sharply. Cellular levels of Mg^{2+}, K^+, total N, and unsaturated fatty acids were low when K^+ was deficient and increased with increasing K^+; cellular sufficiency concentration of K^+ was 1.2% of dry wt. Ca^{2+} had no effect except at toxicity (100 meq/l).

1844. Macfarlane, N.A.A. and J. Maetz. 1975. Acute response to a salt load of the NaCl excretion mechanisms of the gill of *Platichthys flesus* in seawater. Jour. Comp. Physiol. 102: 101-113.

Flounder adapted to seawater were injected IP with a 50% salt content solution based on fish composition. Plasma Na^+ increased from 3.9 to 4.3 g/l and plasma Cl- from 5.4 to 6.1 g/l. Cl^- spaces increased by 25% and Na^+ space by 15%. In non-NaCl-loaded fish, branchial Na^+ exchange is about 2.5 to 3X faster than Cl^- exchange. In response to the load, Na^+ efflux augmented slightly while Na^- influx remained unchanged. Both Cl^- efflux and influx increased by 50 to 80%, the overall effect being an increase of net Cl^- excretion rate. Gill potential in SW was unaltered in salt-loaded fish. Transfer of non-loaded fish into freshwater was followed by an instantaneous decline of both Na^+ and Cl^- effluxes and reversal of gill potential. Addition of K^+ (final concentration 0.39 g/l) into FW (FWK) produced a 150% Na^+ efflux increase, a 40% increase of Cl^- efflux, and simultaneous depolarisation of gill potential. In loaded fish, Na^+ and Cl^- effluxes into FW were enhanced by about 100%. K-dependent Na^+ efflux increased by about 100%, K-dependent Cl^- efflux by at least 400%, while potential decreased in FWK.

Observed fluxes cannot be explained by Goldman equation in terms of free diffusion of Na^+ and K^+ across gills along their electrochemical gradients. Authors suggest that salt loading induced a stimulation of Cl^- pump associated to a Na/K exchange carrier and to a Cl^- exchange diffusion process.

1845. Mackay, N.J., R.J. Williams, J.L. Kacprzac, M.N. Kazacos, A.J. Collins and E.H. Auty. 1975. Heavy metals in cultivated oysters (Crassostrea commercialis = Saccostrea cucullata) from the estuaries of New South Wales. Austral. Jour. Mar. Freshwat. Res. 26:31-46.

Results of a survey of metal levels in the Sydney rock oyster Crassostrea commercialis are reported. Concentrations of Cu, Zn, Cd, Pb and As in oysters sampled from the 19 important production areas in New South Wales were generally low, and in terms of the National Health and Medical Research Council recommendations for these metals there was little or no health risk to consumers. The concentration ranges observed, in mg element per kg wet wt, extended from 3 to 48 for Cu; 80 to 665 for Zn; 0.1 to 1.0 for Cd; 0.3 to 1.3 for Pb and 0.3 to 3.4 for As. The N.H.M.R.C. recommends 30 mg/kg wet for Cu, 1000 for Zn, 2.0 for Cd, 2.0 for Pb and 1.14 for As as trioxide.

Evidence is presented which indicates that metal concentrations decrease with increasing age and wet wt of oysters. In oysters sampled from a single estuary, there is a gradient of increasing metal concentration with increasing distance upstream from the sea. Pollution may be the cause of the relatively high concentrations in oysters from this estuary, but further work will be required to verify this. The variability of metal concentrations in oysters is discussed, and a sampling method is suggested for future monitoring of metals in this species.

1846. Maclean, F.I., O.J. Lucis, Z.Z. Shakh and E.R. Jansz. 1972. The uptake and subcellular distribution of Cd and Zn in microorganisms. Fedn. Proc. Fedn. Amer. Soc. Exp. Biol. 31:699.

Percentages of cadmium uptake by organisms grown in 1.79 mg Cd-109Cl_2/l and Zn-65Cl_2 were 9% for Escherichia coli, a bacterium; 98% for Anacystis nidulans, a blue-green alga; 80% for Chlorella sp., a green alga; and 95% for Crithidia fasciculata, a trypanosomid flagellate. Red alga Chondrus crispus, after 24 hr incubation in seawater containing 1.79 mg Cd-109Cl_2/l, took up 85% of the isotope. Both Cd and Zn were bound to macromolecules in Crithidia. About 65% of Cd and 35% of Zn were associated with a component of 10-12 thousand molecular wt in Anacystis.

1847. Maetz, J. 1970. Mechanisms of salt and water transfer across membranes in teleosts in relation to the aquatic environment. In Benson, G.K. and J.G. Phillips (eds.). Memoirs of the Society for Endicrinology. Hormones and the Environment 18: 1-29.

Teleost "effector-organs" of osmoregulation exhibit widely different functions in maintaining osmotic constancy. Differences in drinking rate are accompanied by modifications of intestinal water-pumping efficiency. Parallel changes in ion-absorption capacity and passive osmotic water permeability are responsible for: increased solute-linked water flow, increased gradient against which absorption is accomplished, and augmented molar ratio of salt absorbed. All of these responses are characteristic of adaptation to higher salinities. In gills, transfer from hypo- to hypertonic media is accompanied by an increase of Na and Cl exchanges. Salt absorption pump is replaced by a salt excretion pump with a different mechanism. Decreased passive water permeability is observed during salt-water adaptation. All alterations induced by external salinity changes involve cellular processes such as cell division and differentiation, and molecular processes such as protein synthesis, particularly of enzyme systems associated with ion pumps and carriers.

1848. Maetz, J. and P. Pic. 1975. New evidence for a Na/K and Na/Na exchange carrier linked with the Cl^- pump in the gill of Mugil capito in sea water. Jour. Comp. Physiol. 102(2):85-100.

Na and Cl efflux and gill potential were recorded simultaneously in seawater (SW)-adapted mullet. After transfer of teleosts to freshwater (FW), an instantaneous decline of the Na efflux was observed, explained by reversal of gill potential which occurred simultaneously. Addition of increasing amounts of K or Na sulphate to FW was followed by a progressive depolarization and by a progressive increase of Na efflux. K was far more efficient than Na in producing these effects. The change in gill potential was not of sufficient magnitude to explain observed increase of Na efflux. Transfer from SW to FW also produced a decline of the Cl efflux. Addition of K to FW enhanced not only the Na but also the Cl efflux. On the basis of these and other studies with SCN authors conclude that the branchial Cl pump is associated with Cl exchange diffusion mechanism and with a Na/K exchange carrier insensitive to potential changes.

1849. Mahrla, Z. 1975. Properties of Ca stimulated ATPase from the sarcotubular fraction of the crayfish muscle. Physiol. bohemoslov. 24:452.

Concentrations of 0.1 to 10 mM Ca^{2+}, in absence of Mg^{2+} ions, stimulated ATPase activity. Sepcific properties of this ATPase are given. Ca^{2+} ions can be substituted for other divalent cations in the sequence: $Ca^{2+} = Mn^{2+} > Co^{2+}$, $Sr^{2+} > Ba^{2+}$, Ni^{2+}.

1850. Mallett, J.C. III. 1972. Environmental aspects of cardiac regulation in the marine teleost Tautoga onitis (Linnaeus). Ph.D. thesis, Univ. Rhode Island, Dept. Zool., Kingston, R.I. 98 pp.

Cardiac regulation in tautogs was studied to determine effects of temperature, salinity, dissolved oxygen (DO) and cadmium on the fish's electrocardiogram (ECG). Cardiac rates from non-intoxicated fish were determined at 6 combinations of temperature and salinity. Hypoxic-induced bradycardia was noted in each instance with a regression of heart rate on DO following an asymptotic regression model of $\hat{Y} = A - BR^X$ where $\hat{Y}$ = estimated heart rate in beats per minute (BPM), A = asymptotic or average maximum heart rate, B = Y intercept, R = instantaneous rate of cardiac increase and X = DO in mg/l. Initial cardiac response to extremely high, lethal concentrations of Cd^{++} (400 mg/l) was bradycardia; greatest inhibition (22 BPM) at 106 min post-exposure gave way to a relative increase to 50 BPM at 280 min post-exposure followed by a decline in rate to mortality. No histological damage to gills was evident after 240 min exposure. Elevated and diphasic T-waves, AV blockage and extrasystolic ventricular activity and progressive dimunition of QRS amplitude were recorded from Cd^{++} intoxicated fish. Cardiographic techniques as an aid in determination of water quality criteria for teleosts are suggested.

1851. Mandelli, E.F. 1975. The effects of desalinization brines on *Crassostrea virginica* (Gmelin). Water Research 9:287-295.

Effects of desalinization brines, diluted with seawater to temperature and salinity levels 5 and 10% above fluctuating non-perturbed environmental levels and characterized by 19 to 43 μg Cu/l, were assessed using juvenile and adult oysters in 60 day seasonal bioassays. Mortality, in 42 μg Cu/l tests, reached 70 and 100% for adults and juveniles, respectively, with greatest mortality occurring during spring and summer. Lowest concentrations of brines tested resulted in decreased growth and enhanced infection of the pathogenic fungus *Labyrinthomyxa marina*, which augmented mortality. Gametogenesis was inhibited by brine dilutions containing 19.2 to 43 μg total Cu/l. Accumulation and subsequent clean water depletion rates reached 6.94 and 3.95 mg Cu/kg/day, respectively, for exposure to 19 to 43 μg Cu/l.

1852. March, G.L., T.M. John, B.A. McKeown, L. Sileo and J.C. George. 1976. The effects of lead poisoning on various plasma constituents in the Canada goose. Jour. Wildlife Diseases 12: 14-19.

Plasma glucose, free fatty acid and uric acid levels were measured in moribund lead-poisoned geese *Branta canadensis*. Lead level in a pooled plasma sample of lead-poisoned birds was 2.9 mg/l *vs* 1.2 mg/l in controls. Plasma glucose levels were only slightly elevated from 292 to 356 mg/100 ml. Uric acid (15.9 mg/l) was significantly higher than controls (6.2) and free fatty acids were significantly lower (727 *vs* 449 μeq/l). Altered plasma levels were attributed to increased protein catabolism and perhaps renal disfunction. Plasma level of growth hormone was unchanged while prolactin in experimentals was unusually high; increased prolactin levels may reflect an effort to stabilize free fatty acids.

1853. Marchand, M. 1974. Considérations sur les formes physico-chimiques du cobalt, manganèse, zinc, chrome et fer dans une eau de mer enriche ou non de matière organique. Jour. Conseil int. Explor. Mer 35(2):130-142.

Using radioisotopes of Co, Mn, Zn, Cr and Fe as tracers, various physico-chemical forms of the isotopes were determined in a natural seawater and the same seawater enriched with marine algal organic matter. In natural seawater, 3 days after introduction of radionuclides, manganese and zinc were mainly in soluble cationic forms (Mn^{2+}, Zn^{2+}). Cobalt appeared in two soluble cationic forms (Co^{2+} and $CoCl^{+}$); a slight anionic or neutral fraction was detected which may correspond to complexes with the ligand Cl^-($CoCl_4^{2-}$, $CoCl_3^-$, $CoCl_2$). Chromium, adsorbed strongly to walls, was present as a soluble chromate (CrO_4^{2-}). Iron was usually found in a colloidal state; the occurrence of an anionic or neutral fraction points to colloidal dispersion rather than a truly soluble form. Addition of organic matter on physico-chemical equilibrium of zinc, chromium and iron is demonstrated by formation of anionic, neutral (iron and chromium) or cationic (zinc) organo-metallic complexes. The action of organic matter is potentiated with increasing insolubility of nuclides. Occurrence of Fe and Cr organic complexes is less frequent at reduced pH.

1854. Maren, T.H. 1962. Ionic composition of cerebrospinal fluid and aqueous humor of the dogfish, *Squalus acanthias*. I. Normal values. Comp. Biochem. Physiol. 5:193-200.

Average Na levels of dogfish plasma, cerebrospinal fluid (CSF), and aqueous humor, in mg/l, were 5870, 6230, and 6350, respectively; for K these levels were 257, 304, and 293 mg/l for plasma, CSF and aqueous humor. Comparison with patterns in other vertebrates was made; the outstanding difference is the lack of K deficit in dogfish CSF.

1855. Maren, T.H. 1972. Bicarbonate formation in cerebrospinal fluid: role in sodium transport and pH regulation. Amer. Jour. Physiol. 222(4):885-899.

In dogfish *Squalus acanthias*, rate constant values for HCO_3^-, Na^+, and Cl^- entry into cerebrospinal fluid (CSF) from plasma were 1.9, 0.19, and 0.14 hr^{-1}, respectively. Composition of CSF as secreted had same Na concentration as plasma, with HCO_3^- much higher and Cl^- lower than plasma. Data suggest that HCO_3^- reaches the CSF by hydroxylation of gaseous CO_2 at the choroid plexus, and probably at glia. Movement of HCO_3^- has an important influence on movement of Na and fluid.

1856. Maren, T.H., P. Wistrand, E.R. Swenson, and A.B.C. Talalay. 1974. The rates of ion movement from plasma to aqueous humor in the dogfish, *Squalus acanthias*. Invest. Ophthalmol. 14(9):662-673.

Aqueous humor dynamics were studied in dogfish using isotopically labeled inulin, Na^-, Cl^-, and HCO_3^-. Fluid production was 100 ul/h, with a turnover rate constant of 0.4 hr^{-1}, which is about half that of mammals. Na^+ diffusion rates, in uM/h from plasma to aqueous is $\geq$25 and from aqueous to vitreous, 420; secretion rate of Na^+ from plasma to aqueous is 25. Rates and concentrations are also given for HCO^- and Cl^-. Sodium and chloride secretion is masked by the diffusion process; neither ouabain nor acetazolamide yield measurable effects on accumulation of these isotopes. Analyses of data suggest that newly formed aqueous has similar Na^+ concentration to plasma, but is high in HCO^- and low in Cl^-. This anion pattern resembles mammalian aqueous humor, and cerebrospinal fluid and endolymph of other vertebrates. These and other data suggest that constant features of formation of these fluids in all phyla are sodium transport, and formation of HCO_3 from CO_2.

1857. Marking, L.L. and T.D. Bills. 1975. Toxicity of potassium permanganate to fish and its effectiveness for detoxifying antimycin. Trans. Amer. Fish. Soc. 104(3):579-583.

Ten species of freshwater teleosts showed LC-50 (96 h) values for potassium permanganate ($KMnO_4$) ranging from 0.75 mg/l with channel catfish Ictalurus punctatus, to 3.6 mg/l with goldfish Carassius auratus. Toxicity of $KMnO_4$ is greatest at low temperatures, increased alkalinity, and elevated pH. $KMnO_4$ is effective in detoxification of antimycin. Half-life for antimycin exposed to 1.0 mg/l of $KMnO_4$ at 12 C, is 10, 7, 8, and 11 minutes at pH's 6.5, 7.5, 8.5, and 9.5, respectively.

1858. Marks, G.W. 1938. The copper content and copper tolerance of some species of mollusks of the southern California coast. Biol. Bull. 75:224-237.

Copper levels in several species of mollusks was determined, with emphasis on variations attributable to age or size. In the snail Helix aspersa, amount of copper per unit wt of tissue increases with increase in size; the reverse was observed in the California sea mussel; in octopus Polypus bimaculatus, Cu remains constant. Samples of Pacific coast seawater contained 0.001 mg of copper per kg. Upper limits of copper tolerance of a few species of marine mollusks, under laboratory conditions for 30 days, is in the range 0.10 to 0.20 mg of added copper per kg seawater. However, the clam Paphia staminea tolerates much higher Cu concentrations.

1859. Martin, J.H. 1969. Distribution of C, H, N, P, Fe, Mn, Zn, Ca, Sr, and Sc in plankton samples collected off Panama and Colombia. Bioscience 19:898-901.

Approximately 130 plankton samples of unknown species composition were collected on both sides of the Isthmus of Panama during wet and dry seasons and analyzed for Fe, Mn, Zn, Sr, Ca, Sc, and Fe.

Abundance and distribution of Fe and Sc is dependent on several factors including settling or transport by bottom scouring currents of inorganic particulate matter which has entered marine environment via runoff. Abundance and distribution of Ca, Sr, and Zn is strongly dependent on standing crop and species composition of phytoplankton and zooplankton.

1860. Martin, J.H. and W.W. Broenkow. 1975. Cadmium in plankton: elevated concentrations off Baja California. Science 190: 884-885.

Plankton, including diatoms and copepods, were collected in the northeast Pacific Ocean and analyzed for cadmium. Concentrations were generally low (2 to 5 mg Cd per kg dry wt) in all samples except for those collected off Baja California where high values (10 to 20 mg/kg) were consistently found on two cruises. Authors suggest that increased Cd concentrations found south of San Diego were due to elevated Cd levels in seawater.

1861. Martin, J.H., P.D. Elliot, V.C. Anderlini, D. Girvin, S.A. Jacobs, R.W. Risebrough, R.L. Delong and W.G. Gilmartin. 1976. Mercury-selenium-bromine imbalance in premature parturient California sea lions. Marine Biology, 35:91-104.

High premature birth rates were observed in sea lions Zalophus californianus since 1968. Liver and kidney from 10 normal parturient, and 10 premature parturient mothers and their pups were analyzed for Hg, Se, Br, Cd, Ag, Cu, Fe, Zn, Mn, K, Na, Ca, and Mg. Results showed that Hg, Se, Cd, and Br levels were significantly higher in livers of normal mothers and that these elements were in balance with each other; this was especially pronounced for Hg, Se, and Br. In mothers with high concentrations of these elements (e.g. Hg greater than 800 μg/g dry wt), atomic ratios of approximately 1 Hg:1 Se:1 Br were observed. Atomic Se:Hg ratios were also near unity in abnormal mothers; however, Br concentrations were always severely depressed in these individuals. Normal full-term pups had higher hepatic levels of Hg and Se, and near-perfect 1:1 Se:Hg atomic ratios were almost always observed. In contrast, liver from premature pups appeared to be deficient in Hg, and consequently, elevated Se:Hg ratios were always found. Premature pups had increased concentrations of Na, Ca, and Br. Levels of these elements were correlated with their Se:Hg ratios. Amounts of Mn and Cu were reduced in premature pups and negatively correlated with Se:Hg ratios. It is suggested that balance between elements is more important than the absolute concentration when possible effects of toxic elements are considered. Bromine may be important in detoxification process involving Se and Hg and perhaps Cd as well; i.e., all dams with Br in balance with Hg, Cd, and Se had normal pups, while those that lacked sufficient Br had a premature pup. The question of whether Hg detoxifies Se is also raised. All normal pups displayed Se:Hg atomic ratios of less than 2.2, while all premature pups exhibited reduced Hg amounts and Se:Hg ratios above 3.4.

1862. Martin, J.H. and A.R. Flegal. 1975. High copper concentrations in squid livers in association with elevated levels of silver, cadmium, and zinc. Marine Biology 30:51-55.

Livers from Loligo opalescens, Ommastrephes bartrami, and Symplectoteuthis oualaniensis were analyzed for Ag, Cd, Cu, Zn, and Fe. Mean concentrations, in mg/kg dry wt, in Loligo from central California were Ag 25, Cu 5,350, Cd 85, Zn 247, and Fe 111. Using highest copper concentration found (15,160), a concentration factor of 2.1 million was obtained. Mean concentrations in Loligo from southern California (in area where silver input was high) were: Ag 45, Cu 8,370, Cd 121, Zn 449, and Fe 87. O. bartrami from open ocean averaged 12 for Ag, 195 for Cu, 287 for Cd, 163 for Zn, and 399 for Fe. S. oualaniensis, from open ocean, contained means of: Ag 24, Cu 1,720, Cd 782, Zn 513, and Fe 319.

1863. Martin, D.F., M.T. Doig and R.H. Pierce. 1971. Distribution of naturally occurring chelators (humic acids) and selected trace metals in some west coast Florida streams, 1968-1969. Florida Dept. Nat. Res., Mar. Res. Lab., Prof. Pap. No. 12, St. Petersburg, Fla.

Concentrations of humic acid, Fe, Mn, Cu and Zn from 14 coastal streams in western Florida were measured to establish relation, if any, on incidence of red tide. Correlations between rainfall, humic acids and heavy metals, particularly Fe, were examined and their significance in development of blooms of Gymnodinium breve were discussed.

1864. Martin, J.-L.M. 1973. Iron metabolism in Cancer irroratus (crustacea decapoda) during the intermoult cycle, with special reference to iron in the gills. Comp. Biochem. Physiol. 46A:123-129.

During intermoult cycle of Cancer, iron shows little variation in exoskeleton, hepatopancreas, hypodeum, hemolymph, and muscle. Storage cells for iron occur in the hepatopancreas. Gills accumulate comparatively large quantities of iron, up to 500 mg/kg wet wt. This accumulation occurs during stage C3 of the intermoult cycle and is maximum in stage C4. Iron is not detectable in gill raphe, but forms a coating around the branchial lamallae. This coating, along with the old gill, will be rejected at ecdysis.

1865. Martin, S.G. 1971. An analysis of the histopathologic effects of copper sulfate on the Asiatic freshwater clam, Corbicula fluminea (Muller). Ph.D. thesis, Univ. of Washington, Seattle, Wash. 109 pp.

Effects of copper sulfate on clam histopathology, behavior and tissue recovery potential, were investigated. Clams exposed to Cu at >250 μg/l for longer than 14 days began to show effects due to starvation; no clams pumped at >500 μg/l. More than half the clams subjected to 50 μg/l and lower pumped actively throughout the experiment; however, some were affected at Cu^{2+} levels of 12 μg/l. At low level exposures to Cu (12 to 50 μg Cu^{2+}/l) initial histopathological changes observed were increase in mucous production of digestive tubules, then hemocytic infiltration and increased mucocyte size in gills, followed by fragmentation, necrosis and cell sloughing in mantle epithelium. At 125 to 250 μg Cu^{2+}/l, gills were affected first, followed by digestive tubules and collecting ducts. At >250 μg Cu^{2+}/l, digestive tubules were first affected, followed by gill and mantle epithelium. The most important histological responses to Cu ion were: partial or complete necrosis in all tissues; hemocytic infiltration and diapedesis; transformation of the mantle, collecting duct, and stomach epithelial tissues; and increased mucous production by hypertrophic gill mucocytes. Clam tissues exposed to relatively high Cu concentrations, accumulated Cu in significant amounts by 7 days; those at medium concentration did not accumulate significant amounts until 15 days. Copper ion accumulations were observed in gill, mantle epithelium, digestive tubules, and hemocytes. Capacity for tissue recovery was high in clams exposed to 12 μg/l, but incomplete or partial in those exposed to higher concentrations, mantle epithelium showed highest recovery potential. Author states that optimal continuous dosage for Asiatic clam control appears to be in the vicinity of 25 μg Cu^{2+}/l.

1866. Massaro, E.J. 1974. Pharmacokinetics of toxic elements in rainbow trout. U.S. Environ. Prot. Agen. Rept. EPA-660/3-74-027. 30 pp.

Hg-203 labelled methylmercury (MeHg) was administered intragastrically in a single dose (0.5 mg Hg/kg = 0.3 μCi/kg) to rainbow trout Salmo gairdneri of mean wt 250 g. Fish were sacrificed from 1.0 hr to 290 days postadministration. Mercury-203 was taken up rapidly by blood, gill, spleen, liver, and kidney and more slowly by muscle, brain, and lens. After 290 days blood, spleen, kidney, liver, and lens had concentration factors (C.F. = tissue Hg conc/Hg dose x final tissue wt/initial tissue wt) of about 1.0. In general, C.F.'s had dropped by at least 2/3 from their maxima except for muscle, brain, and lens in which the C.F.'s remained at maxima; about 64% of the dose still remained in the fish, with skeletal muscle—which comprised about 55% of body weight—containing more than 40% of the residue. Assuming MeHg excretion to be a first order process, there are at least two rates of excretion: a rapid initial rate resulting in a biological half-retention time (HRT) of about 200 days; and a slower, subsequent rate yielding an HRT of more than 1000 days. The latter is apparently governed by rate of release of MeHg from skeletal muscle.

Hemoglobin (Hb) is the main methylmercury (MeHg) transport protein in trout blood. *In vitro*, MeHg is taken up rapidly in 3 min by red blood cells. MeHg binding in RBC is reversible *in vitro* as demonstrated by efflux of Hg from RBC's suspended in protein solutions. MeHg binding in RBC also is reversible *in vivo* as gel filtration chromatography of liver soluble proteins yielded identical elution profiles for MeHg administered as the free salt or bound in RBC's. The number of reactive sulfhydryl (-SH) groups per molecule of Hb was 4, as determined by amperometric titration with MeHgCl. The reactive -SH concentration in RBC was calculated to be at least 20 mM. A mechanism for efflux of MeHg from RBC is proposed involving dissociation of MeHg from Hb; this was initiated by -SH groups outside RBC, and migration of MeHg across membrane as MeHgCl.

1867. Matsumoto, T., M. Satake, J. Yamamoto and S. Haruna. 1964. On the micro constituent elements in marine invertebrates. Jour. Oceanogr. Soc. Japan 20(3):15-19. (In Japanese, English Summary)

Whole organism metal levels, in mg/kg wet wt, in *Octopus* were 39 for Cu, 106 for Zn, 4 for Cd, 1 for Pb, 37 for Fe and 4 for Al. Squid *Sepia*, contained levels of 23 for Cu, 50 for Zn, 0.7 for Cd, 0.4 for Pb, 8 for Fe, and 1.7 for Al. Sea cucumber *Holothuria* and jellyfish *Aurelia* contained respective levels, in mg/kg wet wt, of 1.9 and 0.7 for Cu, 8.7 and 3.4 for Zn, 14.4 and 0.8 for Pb, 50 and 0.9 for Fe, and 73 and 0.6 for Al; *Aurelia* contained 0.1 mg Cd/kg wet wt.

1868. Mauchline, J. and W.L. Templeton. 1966. Strontium, calcium and barium in marine organisms from the Irish Sea. Jour. Cons. perm. int. Explor. Mer. 30:161-170.

Strontium, calcium, and in some cases, barium concentrations have been determined in 15 species of algae, 45 species of invertebrates and 6 species of fish from the Irish Sea. Algal Sr concentrations in mg/kg wet wt, ranged from 0.12 to 0.22 in Chlorophyceae, 0.55

to 1.20 in Phaeophyceae, and 0.02 to 6.40 in Rhodophyceae. Algal Ca concentrations ranged from 15 to 33 in Chlorophyceae, 10 to 28 in Phaeophyceae and 1.7 to 1800 in Rhodophyceae. Algal Ba levels were from 0.09 to 0.44 in Chlorophyceae, 0.05 to 0.38 in Phaeophyceae and 0.05 to 0.36 in Rhodophyceae. Strontium content of invertebrates, in mg/kg wet wt were: 0.31 in sponges; 3.0 to 3.6 in polyzoa; 0.02 to 1.4 in coelenterata; 2.1 in annelida; 0.97 to 17.0 in crustacea; 0.04 to 0.77 in mollusca; 2.3 to 8.8 in echinodermata; and 3.7 to 7.3 in tunicata. Calcium levels were 59 in sponges, 434 to 522 in polyzoa, 1 to 206 in coelenterata, 306 in annelida, 197 to 1920 in crustacea, 5 to 232 in mollusca, 513 to 1458 in echinodermata and 7 to 32 in tunicata. Barium concentrations were 0.22 for sponges, >0.2 for polyzoa, >0.03 to 0.55 in coelenterata, 0.16 in annelida, >0.09 to 0.84 in crustacea, 0.02 to 0.1 in mollusca, 0.2 to 1.20 in echinodermata and 0.07 to 0.1 in tunicata. Strontium concentration in fish bone ranged from 0.01 to 0.06 mg/kg wet wt. Calcium, in mg/kg wet wt, for fish extended from 2 to 10 in flesh and 210 to 258 in bone.

1869. May, D.R. and G.W. Brown, Jr. 1973. Allantoinase from *Eudistylia vancouveri* (Polychaeta): Activation and inhibition by heavy metals. *In* 1972 Research in Fisheries. Ann. Rep. Fish., Univ. Wash., Seattle, Wash.: 66-67.

Marine polychaetes subjected to 7 x 10^{-5} M $HgCl_2$ (14 mg/l Hg) exhibit 50% inhibition of allantoinase, a uricolytic enzyme; allantoinase is activated 13 to 20% in presence of 2.5 x 10^{-8} M to 1 x 10^{-6} M $HgCl_2$. At 2.7 x 10^{-6} M $CdCl_2$ (0.3 mg/l Cd), enzyme was inhibited 50%; but activation occurred at 2.5 x 10^{-8} M to 5 x 10^{-8} M Cd^{+2}. Metals concentrations causing 50% inhibition of allantoinase were: 3.5 x 10^{-5} M $Pb(NO_3)_2$ (7 mg/l Pb); 4.1 x 10^{-5} M $ZnCl_2$ (3 mg/l Zn); and 7.8 x 10^{-5} M $CuSO_4$ (5 mg/l Cu). Low levels of these metals also activated allantoinase. The enzyme is most sensitive to inhibition by metal ions in the order: $Cd^{+2} > Pb^{+2} > Zn^{+2} > Hg^{+2} > Cu^{+2}$.

1870. McBrien, D.C.H. and K.A. Hassall. 1965. Loss of cell potassium by *Chlorella vulgaris* after contact with toxic amounts of copper sulphate. Physiologia Plantarum 18:1059-1065.

Chlorella accumulated Cu from the medium with most of it bound as divalent copper. When levels rose from 1.37 (controls) to 156 mg Cu/kg dry wt, K was released in excess of the number of equivalents of Cu^{2+} entering cells. More Cu was bound under anaerobic than under aerobic conditions; extra uptake was associated with but not stoichiometrically related to increased loss of K. Authors suggest that K is released due to a graded response of a barrier, normally of low permeability, to increasing amounts of bound Cu.

This increase in permeability is considered to be the primary toxic effect of Cu. Cells which lost a considerable proportion of their normal K were capable of subsequent growth.

1871. McBrien, D.C.H. and K.A. Hassall. 1967. The effect of toxic doses of copper upon respiration photosynthesis and growth of Chlorella vulgaris. Physiologia Plantarum 20:113-117.

C. vulgaris cultures subjected to 200 mg Cu^{2+}/l under anaerobic conditions for two hrs, then exposed to anaerobic or aerobic conditions for 2 hrs, exhibited suppressed respiration, and inhibited photosynthesis and growth. A total of 8.2 mg Cu/kg dry wt algae was determined. When experiment was conducted under aerobic conditions of Cu uptake, and cells subsequently exposed for 2 hrs of oxygen-free media, then respiratory inhibition is as marked as anaerobic uptake; however, respiration eventually recovers because growth is not affected as severely as when under anaerobic conditions. It is concluded that extra copper absorbed under anaerobic conditions is directly or indirectly responsible for the greatly increased toxicity to growth, and that this copper is bound to sites not normally available under aerobic conditions. Some aspects of the apparently unique toxic effect of copper suggest that these extra sites are sulphydryl groups.

1872. McCarty, L.S. and A.H. Houston. 1975. Effects of exposure to sublethal levels of cadmium upon water-electrolyte status in the goldfish (Carassius auratus). Jour. Fish Biol. 9: 11-19.

Goldfish exposed to 45 or 380 µg Cd/l for 25 days showed significant reduction of plasma chloride, and increased tissue K and water contents. Specimens in 45 µg Cd/l compensated for most of initial Cd effect, and were characterized only by depressed plasma Na levels. Exposure to 380 µg Cd/l for 50 days produced depression of plasma Na and Cl, and elevation of tissue Na and water content.

1873. McDermott, D.J., G.V. Alexander, D.R. Young and A.J. Mearns. 1976. Metal contamination of flatfish around a large submarine outfall. Jour. Water Poll. Contr. Fed. 48(8):1913-1918.

Metal levels, in mg/kg dry wt of flesh, from Dover sole Microstomus pacificus from a California waste water outfall region and a control region (Santa Barbara Channel) were, respectively: 0.2 and 0.1 for Ag; <3.0 and <3.0 for Cd; <0.2 and <0.2 for Cr; 0.6 and 0.5

for Cu; <2.0 and <2.0 for Ni; 1.3 and <1.1 for Pb; and 39.4 and 38.0 for Zn. Fin erosion was associated with elevated Cr, Al and Fe levels in liver and kidney and depressed Cd, Ti and Al in gonads and heart.

1874. McFarren, E.F., J.E. Campbell and J.B. Engle. 1962. The occurrence of copper and zinc in shellfish. *In* Jensen, E.D. (ed.). Proc. 1961 Shellfish Sanitation Workshop, U.S.D.H.E.W., P.H.S. 1962:229-234.

A wide geographic variation in both Cu and Zn levels of East Coast shellfish was noted. Zinc levels ranged from 310 mg/kg wet wt in lower Chesapeake Bay to 4000 in upper Chesapeake Bay near Baltimore. Oysters contained about 10 to 20X more Cu and 30 to 40X more Zn than clams from the same or nearby areas, and about 200X more Cu and 90X more Zn as mussels from the same area. Oysters with high Zn levels were also high in Cu, although the converse was not apparent.

1875. McHargue, J.S. 1924. The significance of the occurrence of copper, manganese and zinc in shell-fish. Science 60:530.

The following concentrations, in mg/kg dry wt, of Cu, Fe, Mn, and Zn were found in crustaceans and bivalve molluscs: crayfish 75 Cu, 896 Fe, 250 Mn, 320 Zn; mussel 12 Cu, 1325 Fe, 5424 Mn, 750 Zn; clam 16 Cu, 711 Fe, 43 Mn, 1359 Zn; oyster 231 Cu, 208 Fe, 49 Mn, 4284 Zn; lobster (edible meat) 85 Cu, 54 Fe, 12 Mn, 160 Zn; and crabs (entire bodies) 68 Cu, 134 Fe, 16 Mn, 1216 Zn.

1876. McHargue, J.S. 1927. The proportion and significance of copper, iron, manganese and zinc in some mollusks and crustaceans. Trans. Kentucky Acad. Sci. 2:46-52.

Respective copper, iron, manganese and zinc levels, in mg/kg dry wt of shellfish were 12, 1325, 5424 and 750 for a mixed sample of freshwater molluscs, *Unio* and *Anodonta*; 16, 711, 43, and 1359 for clam, *Venus mercenaria*; 23, 208, 49 and 4284 for oysters; 85, 54, 12 and 160 for lobster, *Homarus americanus*, meat; and 68, 134, 16 and 1216 for whole crabs.

1877. McInerney, J.E. 1964. Salinity preference: an orientation mechanism in salmon migration. Jour. Fish. Res. Bd. Canada 21(5):995-1018.

Preference among fry of chum salmon *Oncorhynchus keta*, pink salmon *O. gorbuscha*, chinook salmon *O. tshawytscha*, sockeye salmon

O. nerka, and coho salmon *O. kisutch*, gradually changed from freshwater to saltwater of open ocean salinity. Author proposes that juvenile Pacific salmon use estuarine salinity gradients as directive cues in seaward migration.

1878. McIntosh, A.W. and N.R. Kevern. 1974. Toxicity of copper to zooplankton. Jour. Environ. Quality 3(2):166-170.

For the aquatic zooplankters *Daphnia pulex*, a cladoceran, and *Cyclops* sp., a copepod, LC-50 (96 hr) values for copper sulfate, in mg Cu/l, were 0.028 and >225.0, respectively. Addition of 0.75 mg Cu/l as $CuSO_4 \cdot 5H_2O$ to an outdoor pond resulted in a depression of cladoceran and rotifer populations; within 4 weeks, both showed increasing numbers. Addition of 0.75 mg Cu/l as copper sulfate to a second pond occurred when cladoceran numbers were low; however, a combination of oxygen depletion, H_2S production and released Cu from large masses of decomposing *Chara* apparently suppressed rotifer, copepod, and cladoceran populations. Treatment of 0.25 mg Cu/l to a third pond produced no discernible effects on cladocera. Stomach analyses of green sunfish *Lepomis cyanellus*, indicated that the fish shifted to alternate food sources when cladocera disappeared from affected ponds.

1879. McKim, J.M., G.F. Olson, G.W. Holcombe and E.P. Hunt. 1976. Long-term effects of methylmercuric chloride on three generations of brook trout (*Salvelinus fontinalis*): toxicity, accumulation, distribution, and elimination. Jour. Fish. Res. Bd. Canada 33:2726-2739.

During a 144-wk period, 3 generations of trout were exposed continuously to mean water concentrations of methylmercuric chloride (MMC) of 2.93, 0.93, 0.29, 0.09, 0.03 and <0.010 (control) µg Hg/l. During the first 39 wks the highest concentration (2.9 µg Hg/l) produced deformities and 88% mortality of first-generation adults. At an MMC concentration of 0.93 µg Hg/l, second-generation trout developed deformities and all but one female died during the 108-wk exposure. No significant effects on survival, growth, or reproduction of second-generation trout were noted at any of the lower MMC concentrations. No toxic symptoms were observed in the third generation at the 3 lowest MMC concentrations. Maximum acceptable toxicant concentration (MATC) for brook trout exposed to MMC in water with a hardness of 45 mg/l (as $CaCO_3$) and a pH of 7.5 fell between 0.93 and 0.29 µg Hg/l, and the application factor (MATC/96-h LC-50) lies between 0.004 and 0.013. Accumulation rate of Hg by 8 selected tissues of first-generati[illegible] trout exposed to MMC was relatively rapid at all MMC concentrations tested. The 2-wk tissue Hg:water Hg concentration factors ranged from 1 x 10^3 to 12 x 10^3, depending on tissue, whereas after 28-38 wks of exposure this parameter for both first- and second-generation trout ranged from 6.9×10^3 to 6.3×10^4. Blood, spleen, and kidney accumulated Hg most rapidly and contained highest residues in both first- and second-generation trout followed by liver, gill, brain, gonad, and muscle. There was no significant elimination of Hg from the tissue of first- or second-generation fish, yet a "steady state" (μg Hg/g = constant) was reached in all tissues after 20-28 wks of continuous water exposure. Monomethylmercury made up 90-95% of the total Hg present in muscle. Mean muscle residues in first-generation trout, dying after 16-28 wks of exposure to 2.93 μg Hg/l and in second-generation trout, dying after 64-100 wks of exposure to 0.93 μg Hg/l, were 23.5 and 9.5 μg Hg/g, respectively.

1880. McLean, R.O. 1974. The tolerance of *Stigeoclonium tenue* Kütz to heavy metals in South Wales. Brit. Phycol. Jour. 9:91-95.

The distribution of *Stigeoclonium tenue* and *Cladophora glomerata* in relation to metal pollution by Cu, Pb, Fe, Zn and Mn was studied in 169 river stations in the spring months of 1972. Equal tolerance to Cu, Pb and Zn was demonstrated in both algae, but *Stigeoclonium* showed greater tolerance to Fe, even in conditions of poor nutrient status. Highest concentrations of various metals tolerated by *Stigeoclonium*, in mg/l, were >9.98 for Fe, 0.02 for Cu, 0.20 for Pb, >0.99 for Mn and 0.53 for Zn. For *Cladophora* these were 0.45 for Fe, 0.02 for Cu, 0.22 for Pb, 0.85 for Mn, and 0.42 for Zn.

1881. McLeay, D.J. 1975. Sensitivity of blood cell counts in juvenile coho salmon (*Oncorhynchus kisutch*) to stressors including sublethal concentrations of pulpmill effluent and zinc. Jour. Fish. Res. Bd. Canada 32:2357-2364.

Exposure to zinc concentrations of 0.50 to 1.20 mg/l for 24 hr significantly depressed mean white blood cell-thrombocyte counts in salmon. Decreases were proportionate to Zn concentrations. Red blood cell counts were unchanged.

1882. McLeese, D.W. 1974. Toxicity of copper at two temperatures and three salinities to the American lobster (*Homarus americanus*). Jour. Fish. Res. Bd. Canada 31:1949-1952.

Time to 50% mortality from the lethal threshold 56 ug/l to 1000 ug/l copper, is longer at 5 than at 13 C. Within these concentrations similar effects were observed at salinities of 20 and 30^{o}/oo.

1883. McLeod, G.C., K.V. Ladd, K. Kustin and D.L. Toppen. 1975. Extraction of vanadium (V) from seawater by tunicates: a revision of concepts. Limnol. Oceanogr. 20:491-493.

Tunicates remove vanadium from the aqueous phase as monomeric vanadate. As the seawater circulates through the tunicate, whether for feeding or respiration, assimilation of vanadate may take place. The time constant for extraction is inherently smaller than the pumping time constant (which varies between 2 and 185 ml/h g wet wt), making extraction out of seawater into tunicate's body the slow step in the overall process. Inhibition of vanadium uptake by phosphate or arsenate may be the result of reaction with vanadate to form complexes, as the product may not bind at all, or as well, to the appropriate site on the tunicate. At phosphate levels naturally present in seawater (∿5 μM) complex formation is relatively insignificant.

1884. McLerran, C.J. and C.W. Holmes. 1974. Deposition of zinc and cadmium by marine bacteria in estuarine sediments. Limnol. Oceanogr. 19:998-1001.

Mixed cultures of marine bacteria isolated from sediments of Corpus Christi Harbor, Texas, were examined for their ability to assimilate or precipitate radioactive zinc and cadmium from solution. Test data indicate that during summer, when bacterial activity is at a maximum, bacteria and their metabolic byproducts play a significant role in removal of zinc and cadmium from seawater and their subsequent deposition in marine sediments.

1885. McLusky, D.S. and C.N.K. Phillips. 1975. Some effects of copper on the polychaete *Phyllodoce maculata*. *Estuarine Coastal Mar. Sci.* 3:103-108.

In 21 day tests, Cu was found to be toxic to *P. maculata* at ∿0.08 mg/l, at which level mortality occurred in 9 days. Authors suggest that rate of Cu uptake is the lethal factor rather than amount of Cu accumulated.

1886. McNaughton, S.J., T.C. Folsom, T.Lee, F. Park, C. Price, D. Roeder, J. Schmitz and C. Stockwell. 1974. Heavy metal tolerance in *Typha latifolia* without the evolution of tolerant races. *Ecology* 55:1163-1165.

Clones of the broad-leaved cattail *Typha latifolia*, and soil samples were obtained from the vicinity of a *zinc smelter*, and from a control location. In the smelter location, soil zinc concentration was

385 times higher (5000 mg/kg), cadmium content 37 times higher (73 mg/kg), and lead content 16 times higher (435 mg/kg). No evidence for the evolution of heavy metal tolerance could be detected in which genotypes from both locations were grown on both soils. Growth of genotypes from both locations was inhibited on the heavy metal soil, but not to the extent that would be expected from previous studies of heavy metal effects.

1887. Mendel, L.B. and H.C. Bradley. 1905. Experimental studies on the physiology of the molluscs—second paper. Amer. J. Physiol. 14:313-327.

Liver of *Sycotypus canaliculatus*, a marine gastropod, contains Cu, Zn, Fe, Ca, Mg, and P. Total ash content of liver contains $\sim$8% Cu and $\sim$15% Zn; on a dry wt basis this is about 1.2% Cu and 1.7% Zn. Cu is uniformly distributed in gland cells and connective tissue, comprising 0.4% or $\sim$3 mg/kg dry liver; it is more predominant in greenish pigment cells, averaging $\sim$3% or 8 mg/kg dry liver. Gland cells contain about 2% or 15 mg/kg Zn; and connective tissue averages 1% or 3 mg/kg Zn. Liver compounds are richer in these metals in certain cases than the insoluble proteid combinations formed by precipitation of albumin with metallic salts. Cu and Zn are probably obtained from the food of *Sycotypus*, and retained in liver as reserve material for the processes of haemopoiesis. Both Cu and Zn are present in combination in blood, forming a respiratory proteid peculiar to this animal.

1888. Mendel, L.B. and H.C. Bradley. 1906-1907. Experimental studies on the physiology of the molluscs—third paper. Amer. J. Physiol. 17:167-176.

Extracts of foot muscle from *Sycotypus canaliculatus*, a marine gastropod, closely resembled those of other molluscs. Blood proteins, however, differed in Cu and Zn. Blood analysis gave an average of 0.474% Cu in ash, 0.043% Cu in tissue, 0.305% Zn in ash, and 0.027% in tissue. Hemoglobin was present in some of the more active tissues such as heart and pharynx muscle.

1889. Meyer, D.K. 1962. Effects of mercuric ion on sodium movement through the gills of gold fish. Federation Proc. 11:107-108.

Using radioactive Na, uptake of Na by gills was measured as 0.92 mg Na/100 g fish/hr; loss of Na over same time period was 0.41. When mercuric ion was added at a concentratin of 10^{-5} M, uptake of Na was completely inhibited but loss of Na increased to 4.02 mg/100 g fish/hr. When Hg concentration was reduced to 10^{-6} M, active uptake was reduced by 25% while loss was increased by 43% over control rates. Mercuric ions had no effect, even at 10^{-5} M concentrations, when a 40 g fish received an intraperitoneal injection of 5 mg of 2-3 dithiopropanol.

1890. Milanovich, F.P., R. Spies, M.S. Guram and E.E. Sykes. 1976. Uptake of copper by the polychaete *Cirriformia spirabrancha* in the presence of dissolved yellow organic matter of natural origin. Estuar. Coast. Mar. Sci. 4:585-588.

At copper concentrations at or below 0.08 mg/1, polychaete worms survived at least 20 days *vs* 34 in controls. At 0.10, 0.20 and 0.50 mg Cu/1, worms had an LT-50 of 16, 12 and 5 days, respectively. Uptake of copper by *C. spirabrancha* in 0.04 mg Cu/1 was initially linear until a plateau of approximately 50 mg/kg was reached in two weeks. Tissue Cu content of *C. spirabrancha* exposed to toxic levels was not greater than those surviving indefinitely in 0.08 or 0.06 mg Cu/1. Authors concluded that lethality is not related to total Cu accumulated but to rate of uptake. Dissolved yellow organics, a chemically and physically ill-defined aqueous extract of decaying plant material, had no effect on uptake rate of Cu by worms in seawater media.

1891. Miller, G.E., P.M. Grant, R. Kishore, F.J. Steinkruger, F.S. Rowland and V.P. Guinn. 1972. Mercury concentrations in museum specimens of tuna and swordfish. Science 175:1121-1122.

Mercury levels of museum specimens of seven tuna caught between 1878 and 1909 and one swordfish were determined by neutron activation analysis. The mean Hg concentration in museum specimens is 0.95 ± 0.33 mg/kg dry wt, with a range from 0.53 to 1.51 mg/kg dry wt. Corresponding mean Hg concentration for five recent tuna samples is 0.91 ± 0.47 mg/kg dry wt, with values ranging from 0.44 to 1.53 mg/kg. The mean Hg value of 1.36 ± 0.31 mg/kg for the single swordfish specimen falls within range of values (0.94 to 5.1 mg/kg dry wt) found for "modern" swordfish. These data support the contention that Hg levels present in wide ranging ocean fish are not primarily the consequence of man's pollution but rather of natural origin.

1892. Mishima, J. and E.P. Odum. 1963. Excretion rate of Zn^{65} by *Littorina irrorata* in relation to temperature and body size. Limnol. Oceanogr. 8:39-44.

Following a single ingested dose, elimination of Zn-65 in a marine gastropod exhibited 2 exponential phases: an early rapid loss phase for first 10 days and a much less rapid loss phase thereafter. Biological half-life of the "assimilated pool" of second phase varied inversely with body size and directly with air temperature. Individuals in field excreted tracer more rapidly than those in laboratory. Trends in relation to temperature paralleled expected rate of O_2 consumption. It is tentatively concluded that, after non-assimilated tracer has been eliminated in the early phase, Zn-65 becomes sufficiently bound to biomass so that whole body rate of excretion reflects activity of individual. This technique may provide an index to long-term rate of metabolism in free living animals.

1893. Mitchell, R. and I. Chet. 1975. Bacterial attack of corals in polluted seawater. Microbial Ecol. 2:227-233.

Coral heads of genus *Platigyra* exposed to low concentrations of crude oil, copper sulfate (100 mg/l), potassium phosphate, or dextrose were killed in periods of 5 to 10 days in aquarium studies. The chemicals stimulated production of large quantities of mucus. In aquaria treated with antibiotics to prevent microbial growth *Platigyra* survived exposure to chemical dosages suggesting that microflora were implicated in coral death. Subsequent studies showed that *Desulfovibrio* and *Beggiatoa*, two species of predatory bacteria, were instrumental in destruction of stressed coral colonies.

1894. Monahan, T.J. 1976. Lead inhibition of chlorophycean microalgae. Jour. Phycol. 12:358-362.

Under conditions in which phosphate was growth limiting at pH 6.2, various species of freshwater algae, including *Chlorella pyrenoidosa*, *C. ellipsoidea*, *C. vulgaris*, *Scenedesmus* sp., *Sc. obtusiusculus* and *Selenastrum capricornutum*, first showed toxic effects at 0.5 mg/l lead. *Scenedesmus* spp. and an *Ankistrodesmus* sp. were more tolerant, with toxic effects at 1 mg/l Pb. At pH 8.0, *Selenastrum* developed toxicity at 3 mg/l Pb, regardless of presence of phosphate. When phosphate supply was growth-limiting, 6X more Pb (3 *vs* 0.5 mg/l) was required to demonstrate toxicity with *Selenastrum* at pH 8.0 as opposed to pH 6.2. *Sc. obtusiusculus* was inhibited at 0.5 mg/l in phosphate-limiting medium and developed toxicity at 1 mg/l in media containing phosphate.

1895. Montgomery, H. 1930. The copper content and the minimal molecular weight of the hemocyanins of *Busycon canaliculatum* and of *Loligo pealei*. Biol. Bull. 58:18-27.

Hemocyanin in the marine gastropods *B. canaliculatum* and *B. carica* contained 2.4 g Cu/kg. For squid *L. pealei*, hemocyanin contained 2.5 g Cu/kg.

1896. Moore, M.N. and A.R.D. Stebbing. 1976. The quantitative cytochemical effects of three metal ions on a lysosomal hydrolase of a hydroid. Jour. Mar. Biol. Assn. U.K. 56:995-1005.

Effects of Cu^{2+}, Cd^{2+}, and Hg^{2+} on the cytochemical staining reaction for lysosomal N-acetyl-B-D-glucosaminidase were determined and related to inhibitory effects of these metals on colonial growth rate of the hydroid Campanularia flexuosa. Cytochemical threshold concentrations of 1.2 to 1.9 μg/l for Cu^{2+}, 40 to 75 μg/l for Cd^{2+}, and 0.17 μg/l for Hg^{2+}, are comparable to known environmental levels and are about 10X lower than those obtained by measuring colony growth rates. Pretreatment of colonies with Cu^{2+} did not adapt its tolerance although there was evidence of cumulative toxicity of Cu^{2+} and possible accumulation in endodermal cell lysosomes. Toxicity of Cu^{2+} may be due to decreasing stability of lysosomal membranes, thus increasing level of free glucosaminidase activity.

1897. Morisawa, M. and H. Mohri. 1974. Heavy metals and spermatozoan motility. II. Turbidity changes induced by divalent cations and adenosinetriphosphate in sea urchin sperm flagella. Experim. Cell Res. 83:87-94

A marked increase in turbidity was caused when heavy metals, such as Cd^{2+} and Zn^{2+}, in relatively low concentrations were added to suspensions of either intact flagella or axonemes isolated from sea urchin spermatozoa. Mg^{2+} and Ca^{2+} were much less effective, while Na^+ and K^+ were without effect. The efficiency of divalent metal ions in producing turbidity increase of suspensions showed the following order, at 0.5 mM concentrations: $Cd^{2+} > Cu^{2+} > Zn^{2+} > Fe^{2+} > Hg^{2+} > Ni^{2+} > Co^{2+} > Mn^{2+} > Sr^{2+} > Ca^{2+} > Mg^{2+}$. The monovalent cations Na^+ and K^+ had little effect on turbidity even when concentrations were raised to 0.1 M. The turbidity increase was almost abolished by adding equivalent amounts of EDTA or pyrophosphate. Addition of ATP to the metal-treated suspensions of flagella also brought about a decrease in turbidity. ADP was not as effective as ATP and little decrease was observed with AMP. The same was true with other nucleoside phosphates. Within a certain range of concentrations Cd^{2+} and Zn^{2+} caused fluctuations in turbidity, which gradually decayed. ATP restored the fluctuations which had once disappeared. The phenomenon could not be observed with samples after long standing, heating, sonication or treatment with 8 M urea. Similar results were obtained with suspensions of microtubules isolated from the flagella. The observed changes in turbidity are discussed in connection with flagellar movement.

1898. Morris, R.J. 1971. Seasonal and environmental effects on the lipid composition of Neomysis integer. Jour. Mar. Biol. Assn. U.K. 51:21-31.

Salinities between 5 and 30^{o}/oo did not influence fatty-acid composition of this brackish water mysid.

1899. Morris, O.P. and G. Russell. 1974. Inter-specific differences in responses to copper by natural populations of *Ectocarpus*. Brit. Phycol. Jour. 9:269-272.

The alga *Ectocarpus siliculosus* showed greater growth in seawater containing up to 0.5 mg Cu/l than *E. fasciculatus*, a different species of the same genera collected from the same region. The greater tolerance shown by *E. siliculosus* may result from immigration of Cu-tolerant individuals from highly selective habitats nearby. Authors suggest that *E. siliculosus* is a more variable species than *E. fasciculatus*, and therefore more readily affected by natural selection.

1900. Muller, A.A. and R. Mosley. 1976. Availability, uptake and translocation of plutonium within biological systems: a review of the significant literature. U.S. EPA Rept. 600/3-76-043. Off. Res. Dev., Envir. Monit. Support Lab., Las Vegas, Nev. 96 pp.

A selective literature review is presented on plutonium and its cycling through biological systems, including algae, molluscs, fish and annelids. Incorporation of particulates within aquatic bottom sediments may isolate Pu and prevent dissolution for long time periods, but occasional violent agitation may cause Pu release and subsequent biological uptake. Concentrations are higher in animals associated with sediment than water column. Food chain amplification has been observed in mussels and starfish. A bibliography of 432 references is included.

1901. Mullin, J.B. and J.P. Riley. 1956. The occurrence of cadmium in seawater and in marine organisms and sediments. Jour. Mar. Res. 15(2):103-122.

Mean cadmium concentration found in waters of the Irish Sea and of the English Channel was 0.113 ug/l, with values ranging from 0.024 to 0.25 ug/l depending upon station and season. Average copper concentration in the Irish Sea was 13.7 ug/l with range of 8.7 to 17.3 ug/l. It is probable that variations are due to adsorption or utilization of the elements by plankton outbursts or to adsorption by detritus.

Occurrence of cadmium in green, red, and brown algae, protozoans, porifera, coelenterata, crustacea, molluscs, and echinoderms (dried at 110 C) has been observed; concentrations varied between 0.134 (*Laminaria digitata*) to 16.4 mg/kg (*Patella vulgata*) and 37.9 mg/kg in soft parts of *Nucella lapillus*. The distribution of Cd in various organs of *Pecten maximus*, *Buccinum undatum*, *Chlamys opercularis*, and *Porania pulvillus* has been investigated: values in calcareous shells are usually <0.02 mg/kg, muscle contains about 1.5 mg/kg, and high concentrations (up to 500 mg/kg) are found in digestive glands and renal organs of molluscs. A representative selection of marine sediments has been analyzed: mean Cd values for diatomaceous oozes is 0.39 mg/kg, globigerina oozes 0.42; and radiolarian oozes 0.45. Two manganese nodules contained 8.4 and 5.1 mg/kg of cadmium, respectively; thallium (ca 2 mg/kg) was also detected in each case.

1902. Mullins, L.J. 1950. Osmotic regulation in fish as studied with radioisotopes. Acta phys. Scandinav. 21:303-314.

The drinking rate of sticklebacks *Gasterosteus aculeatus* upon transfer from fresh to seawater was $\sim$4% of the body weight per hour. This is equal to 350 mg Cl/kg/hr, 8 mg K/kg/hr and 230 mg Na/kg/hr. Permeation of gill membrane by Na-24, K-42, Br-82, and P-32 was measured in freshwater. For Na-24, exchange rate was equal to $\sim$1% of total amount present in body/hr, or $\sim$14 mg/kg/hr. For K-42 in fresh and seawater, exchange rates were 6 and 12 mg/kg/hr, respectively. If one considers that exchange proceeds only with extracellular space K, the rate is about equal to that for Na.

1903. Murphy, T.P. and D.R.S. Lean. 1976. Blue-green algae: Their excretion of iron-selective chelators enables them to dominate other algae. Science 192:900-902.

The ability of blue-green algae to suppress other algae during blue-green algal blooms may be determined by the availability of iron. Iron deprivation induces production of hydroxamate chelators, which appears to be the suppressant agent. In field studies, periods of nitrogen fixation coincided with rapid uptake of Fe-55, supplied as $FeCl_3$. There was no change in flux of iron from sediments. When Fe was not in high demand, blue-green algae comprised about 30% of the phytoplankton biomass. During periods of rapid Fe uptake, blue-green algae increased to $>90\%$ of phytoplankton biomass. In 2 weeks, these blooms were followed by 65% and 50% reductions each in phytoplankton biomass. To test the hypothesis that blue-green algal suppression of other algae may have been mediated by hydroxamate siderochromes, ultrafiltration experiments were conducted. These showed that microbes produced an organic compound with molecular weight of about 1000 capable of solubilizing iron. Colorimetric assay showed that bound hydroxymates were present only during periods of rapid Fe-55 uptake. Effects of the hydroxamate chelate of axenic *Anabaena flos-aquae* on *Scenedesmus basiliensis* included marked growth inhibition; authors concluded that the hydroxamate chelate and not a toxin was responsible.

1904. Myslik, G. and T.C. Hutchinson. 1971. Algal strains resistant to heavy metals from isolates of lakes in the Sudbury smelting region. Amer. Jour. Botany 58:483. (Abstract)

In laboratory tests, nickel and copper were highly toxic to laboratory algal strains at levels present in many lakes of the Sudbury smelting region; Ni and Cu showed synergistic effects. Isolates from sparse algal flora in some heavily polluted lakes indicated a high tolerance to normally toxic levels of these metals.

1905. Nagy, J. and G. Denes. 1976. Iron-requiring mutant of *Escherichia coli* carrying a deletion on the *aro G* - *nad A* region of the chromosome. Jour. Bacteriol. 128:490-491.

A mutant of *E. coli* K-12 carrying a deletion in the *aro G* - *nad A* region of the genome requires a high concentration of Fe for growth. After 4 hrs, growth at 50 μM FeSO$_4$ is about 5X greater than growth at 1 μM FeSO$_4$. This mutant shows a growth response to citrate and is chromium sensitive. Addition of 0.1 mM CrCl$_3$ decreases growth by 50% after 4 hrs. Authors suggest that deletion mutant lost a gene between *aro G* and *nad A* which is a component of the enterochelin-dependent iron transport system.

1906. Nakamura, M. 1974. Experimental studies on the accumulation of cadmium in the fish body (*Tribolodon*). Jap. Jour. Public Health 21:321-327. (In Japanese, English summary)

Tribolodon fry were reared in water containing 0.005, 0.01, and 0.05 mg Cd/1, and in Cd-free water. Death corresponded with mass and age of fry. Fish began to die on the 385th day in 0.01 mg Cd/1 with 68% of these deformed, and on the 413th day in 0.005 mg Cd/1 with 65% deformed. Accumulation of Cd increased with mass and age of fish, reaching 18 mg/kg in 0.05 and 0.01 mg Cd/1, and 11 mg/kg in 0.005 mg Cd/1. Liver and kidney had highest values of Cd (55 mg/kg, compared to 2.7 mg/kg for control) while flesh had lowest levels (1.5 mg/kg, compared to 0.6 for control). Growth differences were apparent between experimental and control fish over the 27 month test period, with inferior growth occurring even in 0.005 mg Cd/1. Author concludes that Cd hinders bone growth.

1907. Nakatani, R.E. 1966. Biological response of rainbow trout (*Salmo gairdneri*) ingesting zinc-65. *In* Disposal of Radioactive Wastes into Seas, Oceans, and Surface Waters. Int. Atom. Ener. Agen., Vienna, Austria: 809-823.

Trout were force fed Zn-65 at 2-3% of average body wt daily. After a single dose fish rapidly excrete Zn-65 for several days, primarily through gastrointestinal tract and gills. Highest Zn-65 concentrations were in gill, G.I. tract and bone. G.I. tract contained 30-50% of body burden after both chronic and single feeding. Little Zn-65 was excreted in urine. Trout fed 0.01, 0.1 and 1.0 μCi Zn-65/g fish daily for 17 weeks did not differ significantly from controls. Growth of Zn-65 fed fish exceeded controls with no mortalities. Fish fed 10 μCi Zn-65/g fish for 10 weeks exhibited no anomalies in blood hematocrit, hemoglobin or erythrocytes; however, leucopenia was indicated. Histopathological evidence of tissue damage was observed only in gill filaments. Because trout with 10,000X greater burden of Zn-65 than river fish showed no detrimental effects, authors concluded that Columbia River fish populations are not adversely affected by present levels of Zn-65 contamination.

1908. Negilski, D.S. 1976. Acute toxicity of zinc, cadmium and chromium to the marine fishes, yellow-eye mullet (Aldrichetta forsteri C. & V.) and small-mouthed hardyhead (Atherinasoma microstoma Whitley). Austral. Jour. Mar. Freshwater Res. 27:137-149.

For juvenile mullet in static tests, the acute incipient lethal level for Zn, the LC-50 (168 h) level for Cd, and LC-50's (96 h) levels for Cr^{3+} and Cr^{6+} were 9, 16, 53 and 24 mg/l, respectively. Highest metal levels, in mg/l, that did not cause death were 5, 10 and 13.5 mg/l for Zn, Cd and Cr, respectively. For pre-adult hardyhead, the acute incipient lethal level for Zn and Cd LC-50 (168 h) were 33 and 21 mg/l, respectively. In continuous-flow tests with mullet, acute incipient lethal level for Zn, Cd LC-50 (120 h), and Cr^{6+} LC-50 (96 h) were 12, 14 and 31 mg/l, respectively. Symptoms produced by Zn poisoning included fin erosion, impaired swimming ability, dark color, and surfacing behavior. For hardyhead, incipient lethal levels for Zn and Cr and LC-50 (168 h) value for Cd were 37, 36 and 15 mg/l, respectively. Toxicity of Zn to mullet appeared to increase with temperature.

1909. Nehring, R.B. 1976. Aquatic insects as biological monitors of heavy metal pollution. Bull. Envir. Contamin. Toxicol. 15: 147-154.

LC-50 (14 d) values for mayfly Ephemerella grandis, in mg/l, were: 0.18 to 0.20 for Cu; 3.5 for Pb; <0.001 for Ag; and >9.2 for Zn. Stonefly Pteronarcys californica had LC-50 (14 d) values of 10.1 to 13.9 for Cu; >19.2 for Pb; 0.004 to 0.009 for Ag; and >13.9 for Zn. Insects were more tolerant to metals screened than fish. Insects concentrated metals in relative proportion to occurrence of metal in the stream by some predictable, reproducible factor. These data, together with field tests, indicate that aquatic insects may be effective biological monitors of heavy metal pollution where fish-kills are involved.

1910. Nelson, D.A., A. Calabrese, B.A. Nelson, J.R. MacInnes and D.R. Wenzloff. 1976. Biological effects of heavy metals on juvenile bay scallops, *Argopecten irradians*, in short-term exposures. Bull. Environ. Contamin. Toxicol. 16(3):275-282.

LC-50 (96 h) values for tests conducted at 25°/oo salinity and 20 C for scallops were 0.033 mg/l of silver, 0.089 mg/l of mercury, 1.48 mg/l of cadmium, and 3.49 mg/l of arsenic. Scallops exposed to 0.94 mg Cd/l or 0.022 mg Ag/l for 96 hr exhibited respective oxygen consumption rates that were 12.9% and 14.7% higher than controls. After exposure for 96 hr to 0.01 mg/l of Ag, 0.75 mg/l of Cd, 0.04 mg/l of Hg or 2.0 mg/l of As, whole juvenile scallops contained, in mg/kg wet wt, 3.1 Ag, 49.4 Cd, 48.9 Hg, or 29.2 As, respectively.

1911. Nelson, D.J. 1962. Clams as indicators of strontium-90. Science 137(3523):38-39.

Analysis of specific activities of Sr-90 in shells of freshwater clams (Unionidae) showed that Sr-90 released to the Tennessee River system remained in solution and that concentrations to a distance of 800 km from the release site can be predicted on basis of dilution of contaminated White Oak Creek water by uncontaminated Clinch-Tennessee River water. Strontium content of 190 shells representing 15 species ranged from 150 to 550 mg/kg and varied with species, age within species, and shell growth rate. Average concentration factor (Sr/gm shell:Sr/ml water) for Sr in shells immediately downstream from White Oak Creek was 4.8×10^3 which is in good agreement with 6.5×10^3, based on monitoring data for water.

1912. Nelson, D.J., J.W. Gooch, N.A. Griffith and S.A. Rucker. 1971. White Oak Lake Studies. *In* Oak Ridge Nat. Lab. Ecol. Sci. Div. Ann. Prog. Rep. ORNL-4634, Avail. from NTIS, U.S. Dept. Comm., Springfield, VA: 104-106.

Food habits and accumulation of Cs-137, Co-60, Ru-106, Sb-125, and Zn-65 in shad *Dorosoma cepedianum*, goldfish *Carassius auratus*, and bluegill *Lepomis macrochirus* from White Oak Lake, Tennessee, were studied over a period of 14 months. Of 272 fish analyzed Ru-106 was found in 42 specimens, Sb-125 in 15, and Zn-65 in 13. Cesium-137 concentrations in all three species followed a seasonal cycle with minimum concentrations in summer and higher concentrations in winter. Shad had the highest Cs-137 concentration with 49.2 pCi/g fresh wt, then goldfish with 23.6, and bluegill with 19.2 (water=0.16 pCi/ml). Low concentrations in bluegill are probably due to inclusion of sediments in digestive tracts of chironomid larvae, and this in turn could interfere with absorption of Cs-137 from food. The preponderance of ingested algae from which Cs-137 was readily assimilated accounted for higher Cs-137 concentrations in goldfish. Piscivorous food habits of shad explains their high Cs-137 concentration if "trophic level effect" concept is applied. In water with Co-60 content of 0.095 pCi/ml, goldfish contained more Co-60 (4.6 pCi/g fresh wt) than shad (2.9 pCi/g fresh wt) or bluegill (2.4 pCi/g fresh wt) and were also the species which ingested more algae. Bluegills and shad are essentially carnivores and have lower Co-60 concentrations, suggesting that Co-60 obtains its maximum concentrations in primary producers.

1913. Nelson, D.L. and E.P. Kennedy. 1971. Magnesium transport in *Escherichia coli*. Jour. Biol. Chem. 246(9):3042-3049.

Energy-dependent transport of Mg^{2+} into bacteria, *E. coli*, was inhibited by 590 μg Co^{2+}/l. Co^{2+} substituted for Mg^{2+} in promoting efflux of cellular Mg^{2+}. Accumulation of Co^{2+} was energy dependent; maximum rate and extent of Co^{2+} uptake were similar to those of Mg^{2+}, although affinity for Co^{2+} was one-tenth that for Mg^{2+}. Co^{2+} uptake was inhibited by 240 μg Mg^{2+}/l. Intracellular Mg^{2+} exchanged readily with external Mg^{2+}, but Co^{2+} within cells did not easily exchange with Mg^{2+} or Co^{2+} in medium. Exposure to a low level of Co^{2+} in absence of Mg^{2+} killed cells, but Mg^{2+} protected against lethal effect of Co^{2+}. Conditions which prevented Co^{2+} uptake, such as low temperature, or deprivation of an energy source, reduced lethality of Co^{2+}. A mutant selected for resistance to Co^{2+} had a decreased capacity to transport both Co^{2+} and Mg^{2+}. Authors concluded that Co^{2+} is transported into cells of *E. coli* by the same system responsible for Mg^{2+} transport.

1914. Nelson, J.D., Jr. and R.R. Colwell. 1975. The ecology of mercury-resistant bacteria in Chesapeake Bay. Microbiol. Ecology 1:191-218.

Total ambient mercury concentrations in sediment (7-860 μg/kg) and in water (0.07-0.49 μg/l) and numbers of mercury resistant, aerobic heterotrophic bacteria at 6 locations in Chesapeake Bay were monitored over a 17 month period. Mercury resistance expressed as proportion of total, viable, aerobic, heterotrophic bacterial population reached a reproducible maximum in spring and was positively correlated with dissolved oxygen concentration and with sediment Hg concentration and negatively correlated with water turbidity. A relation between Hg resistance and metabolic capability for reduction of mercuric ion (Hg^{+2})

to the metallic state (Hg^0) was established by surveying a number of $HgCl_2$-resistant cultures. The reaction was also observed in microorganisms isolated by differential centrifugation of water and sediment samples. Hg^{+2} exhibited an average half-life of 12.5 days in presence of approximately 10^5 organisms/ml. $HgCl_2$ or phenylmercuric acetate (PMA) at levels as low as 1.2 μg/l inhibited a measurable portion of the total population. Cultures resistant to 6 mg/l of $HgCl_2$ and 3 mg/l PMA were classified into 8 generic categories. Pseudomonas spp. were the most numerous of those bacteria capable of metabolizing both compounds; however, PMA was more toxic and more selective for Pseudomonas. The Hg-resistant generic distribution was distinct from that of total bacterial generic distribution and differed between water and sediment, positionally and seasonally. Proportion of nonglucose-utilizing mercury-resistant Pseudomonas spp. was found to be positively correlated with total bacterial Hg resistance. It is concluded that numbers of Hg-resistant bacteria as established by plate count can serve as a valid index of in situ Hg^{2+} metabolism.

1915. Nelson, J.S. 1968. Salinity tolerance of brook sticklebacks, Culaea inconstans, freshwater ninespine sticklebacks, Pungitius pungitius, and freshwater fourspine sticklebacks, Apeltes quadracus. Canad. Jour. Zool. 46:663-667.

The salinity tolerance of Culaea, Pungitius, and Apeltes was studied at 8, 12, 16, and 20 C. Results were compared with the tolerance of Pimephales promelas, Notemigonus crysoleucas, and Umbra limi by increasing salinity in steps of 10% seawater (3.5^o/oo) at regular intervals. Culaea had a significantly lower salinity tolerance than Pungitius and Apeltes but had a significantly higher salinity tolerance than Pimephales, Netemigonus, and Umbra. Culaea recovered when returned to freshwater after an abrupt transfer to 100% seawater for 1.75 hr or less. In Culaea, temperature had an effect on salinity tolerance but neither light duration nor acclimation in 20% seawater had any measurable effect. Apeltes had a significantly higher salinity tolerance than Pungitius at 8 C but not at 16 C. At 16 C most feeding and fanning activity ceased at 60, 80, and 110% seawater, in Culaea, Pungitius, and Apeltes, respectively. In the Gasterosteidae the order of decreasing salinity tolerance and increasing utilization of the freshwater habitat is: Spinachia, Apeltes, Gasterosteus, Pungitius, and Culaea. Biogeography of these species is discussed.

1916. Nelson, V.A. and A.H. Seymour. 1972. Oyster research with radionuclides. A review of selected literature. Proc. Natl. Shellfish Assoc. 62:89-94.

Zn-65 concentrations of 10^{-4} Ci/l will produce harmful effects on oyster larvae. Biological half-lives (time for half of substance to leave body due to biological processes) for Zn-65 in adult Pacific oysters Crassostrea gigas, was 250 days for first 23 days of study, 160 days during four month spawning season, and 970 days during remainder of year (winter).

Uses of radionuclides in oyster research from previous studies are also discussed. These include depuration studies, radionuclides as metabolic tracers, determination of filtration and feeding rates using radionuclide-tagged algae, determination of shell formation and growth rate, radionuclides as a field tag, trace element determination by activation analysis, and genetic studies using radiation-increased mutation rates.

1917. Nelson, V.A. and A.H. Seymour. 1976. Amchitka radiobiological program progress report January 1975 to December 1975. NVO-269-27, Univ. Washington, Lab. Radiation Ecol., Seattle, Wash. 47 pp.

Radioactivity levels attributable to Be-7, K-40, Zr-95, Nb-95, Ru-103-106, Sb-125, Cs-137, Ce-144, and Eu-155 were determined for marine teleosts, sponges, and algae; for freshwater teleosts, alga, mosses, higher plants; and for terrestrial groups. It is part of a program started in 1970 to provide a continuing documentation of radionuclides, both naturally occurring and man-made, in biological and environmental samples from Amchitka and environs. Unexpected combinations or concentrations of radionuclides would indicate presence of newly-added radionuclides to the environment, presumably from fresh fallout, nuclear-powered vessels, or from nuclear detonations at Amchitka Island.

1918. Nevissi, A. and W.R. Schell. 1975. ^{210}Po and ^{239}Pu - ^{240}Pu in biological and water samples from the Bikini and Eniwetok atolls. Nature 255(5506):321-323.

Measurements of radioactivity in water and biological samples from Bikini and Eniwetok lagoons indicate that although samples were collected from the most plutonium-polluted waters of the world, values of the naturally produced radionuclide, polonium-210, were usually greater by up to 100X than those for plutonium-239 and 240, both of which are produced by nuclear detonations. For fishes, Po-210 activity is highest in bone, decreasing in order in liver, viscera and muscle. Although bone and liver have been reported as major repositories for plutonium, the Pu content of the single bone samples reported was at the detection limit of 0.001 d/m/g wet wt. The high concentrations of

Po-210, Pu-239 and Pu-240 in viscera and viscera minus liver (convict surgeon fish), together with the fact that algae in diet of these species concentrates those radionuclides from seawater, seems to support the idea that both radionuclides enter the fish through the food chain. Highest Pu-239 and Pu-240 contents in water column were found in areas where the highest activity of those radionuclides occurred in sediments, as reported for Bikini. The highest Po-210 concentration was found outside the lagoon in deep ocean waters. One possible explanation could be that biological uptake results in a shorter resident time of Po-210 - Pb-210 in the lagoon. The concentration of Pb-210 in the particulate phase, (>0.3 μm in size) was less than 10% of the total; the concentrations of Pu-239 and Pu-240 in the particulate phase varied from 2 to 60% of the total depending on collection site. The overall result indicates that inside the lagoon the radioactivity values of plutonium were more variable than those of Po-210. All specimens measured exhibited concentration factors for Po-210 up to 100X greater than those for Pu-239,-240 with the exception of samples of turtle liver and surgeon fish viscera. Authors concluded that plutonium radioactivity is only a fraction of the natural polonium radioactivity, and that a greater radiation dose to marine organisms of Bikini and Eniwetok lagoons would be received from Po-210 than from plutonium-239 and -240.

1919. Newton, L. 1944. Pollution of the rivers of West Wales by lead and zinc mine effluent. Ann. Appl. Biol. Brit. 31:1-11.

Studies on effects of lead and zinc on plant and animal life of Cardiganshire streams showed that Zn had greater impact on plants than Pb. The greater toxicity of zinc is a primary cause of the scarcity of vegetation on mine detritus and in rivers. Maximum non-lethal concentrations of Zn, in mg/kg, were: 0.2 for pond snail *Limnaea pereger*, and freshwater limpet *Ancylastrum fluviatile*; 0.3 for freshwater shrimp *Gammarus pulex*; 0.2 to 0.5 for mayfly nymph *Chloeon simile*; 30.0 for planarian *Polycelis nigra*; and 500.0 for water-boatman, stonefly nymph, dragonfly larvae, and trichopteran larvae. *Ranunculus aquatilus* (an aquatic flowering plant) was very sensitive to Pb or Zn pollution, and first to disappear when traces of Pb or Zn were present. Fish mortality was not due primarily to fragments of lead grit which caused clogging and inflammation of the gills, but rather to formation of an adsorption complex of heavy metals upon the gills plus an excess secretion of mucus; together these caused suffocation following acute respiratory distress.

1920. Nielsen, E.S. and H.B. Laursen. 1976. Effect of $CuSO_4$ on the photosynthetic rate of phytoplankton in four Danish Lakes. Oikos 27:239-242.

Photosynthetic rate of phytoplankton in water samples from four lakes was altered by the addition of $CuSO_4$. Cu had its maximum adverse effect on photosynthesis at concentrations of 125 μg/l and higher. Among factors which influenced toxic action of Cu^{2+}, were: taxonomic composition of phytoplankton (blue-greens were most sensitive); biomass; humus content of water; temperature; and pH. Although addition of 25 μg/l Cu in three of the lakes decreased photosynthesis considerably, in the fourth lake—a brown-water lake—an increase occurred. In the brown-water lake, humus bound Cu^{2+} so effectively that it was probably present in very low concentrations in the water.

1921. Nielson, E.S. and S. Wium-Andersen. 1972. Influence of copper on photosynthesis of diatoms, with special reference to an afternoon depression. Verh. Internat. Verein. Limnol. 18: 78-83.

The addition of 3 or 6 μg Cu/l to cultures of Nitzschia palea reduced photosynthesis to levels as low as 65% and 10%, respectively, of Cu-free control values. Susceptibility to Cu was highest during darkness in a light-dark regimen of 12:12. These results suggest alternative explanations for previous work using water contaminated with up to 3 μg Cu/l.

1922. Niimi, A.J. and Q.N. LaHam. 1975. Selenium toxicity on the early life stages of zebrafish (Brachydanio rerio). Jour. Fish. Res. Bd. Canada 32:803-806.

Embryos at four stages of development, and newly-hatched larvae of zebrafish were exposed to selenium concentrations of 0.5, 1, 3, 5, and 10 mg/l in freshwater to establish toxic levels at different stages. Embryo mortality was negligible at all concentrations. Following hatching, mortality among larvae sharply increased at concentrations of 3 mg/l or greater, regardless of embryonic stage when exposed; over 90% of larvae died within 10 days of hatching in most cases. The mortality rate for larvae exposed to selenium after hatching was slightly less.

1923. Noel-Lambert, F. 1976. Distribution of cadmium, zinc and copper in the mussel, Mytilus edulis. Existence of cadmium-binding proteins similar to metallothioneins. Experientia 32:324-325.

In mussels, Zn and Cu are principally associated with high molecular wt proteins. The same distribution is observed for Cd in untreated mussels. But in chronically Cd-intoxicated animals (90 day exposure to 5 μg Cd/l), the metal is principally bound to low molecular wt proteins synthesized by mussels and quite similar to metallothioneins of vertebrates.

1924. Norstrom, R.J., A.E. McKinnon, and A.S.W. DeFreitas. 1976. A bioenergetics-based model for pollutant accumulation by fish. Simulation of PCB and methylmercury residue levels in Ottawa River yellow perch (Perca flavescens). Jour. Fish. Res. Bd. Canada 33:248-267.

A pollutant accumulation model based on pollutant biokinetics coupled to fish energetics was formulated to predict concentrations of PCBs and methylmercury in tissues of yellow perch. Metabolic rate expression includes a growth-dependent term for estimating the contribution to metabolism of seasonal and annual growth in each age-class. Uptake of pollutant from food is based on caloric requirements for respiration and growth coupled to concentration of pollutant in food and its dietary assimilation efficiency. Uptake of pollutant from water is based on flow of water past the gills for respiration, concentration of pollutant in water and efficiency of its assimilation by gills. Pollutant clearance, related to body wt raised to the power of -.58, is independent of metabolic rate. Under steady state conditions of chronic exposure, predicted ratio of uptake to clearance is roughly constant at all weights, and the slope of a curve of log pollutant concentration in tissues vs log body wt can be used to establish the exponent of body wt for clearance.

1925. Noshkin, V.E., R.J. Eagle and K.M. Wong. 1976. Plutonium levels in Kwajalein lagoon. Nature 262:745-748.

Plutonium-239,-240 levels in fish (primarily mullet, surgeon fish and goatfish species) from Kwajalein and Enewetak Atolls are not significantly different. This suggests that Kwajalein Atoll contains significantly more environmental plutonium than expected from worldwide fallout levels alone, although no plutonium levels greater than fallout concentrations have been detected in lagoon water. High levels in the fish have not been explained and raise questions concerning validity of concentration factors.

1926. Noshkin, V.E., Jr. and C. Gatrousis. 1974. Fallout ^{240}Pu and ^{239}Pu in Atlantic marine samples. Earth and Planetary Science Letters 22:111-117.

Mass spectrometric analyses of low levels of global fallout plutonium separated from Atlantic marine samples have differentiated fallout Pu-239 and Pu-240 in aquatic samples for the first time.

Results show no single characteristic Pu-240/Pu-239 ratio in marine samples; the observed range is from 0.11 to 0.27 on an atom basis; sediment cores ranged from 0.11 at 4810 m to 0.27 at 4920 m; *Sargassum* had a 0.20 ratio, plankton a 0.24 ratio, and salps a 0.21 ratio. There are indications that differences exist in the chemical or physical form of plutonium from atmospheric fallout in Atlantic surface water and that selective concentration in surface organisms is occurring. No single Pu-240/Pu-239 value is found in pelagic sediments collected from different depths and locations. Discounting sources other than fallout, our results show that the plutonium deposited at any given time since atmospheric testing began may have carried a unique Pu-240/Pu-239 tag. This label may be useful to trace fallout plutonium through biogeochemical cycles.

1927. Noshkin, V.E., K.M. Wong, R.J. Eagle and C. Gatrousis. 1975. Transuranics and other radionuclides in Bikini Lagoon: Concentration data retrieved from aged coral sections. Limnol. Oceanogr. 20(5):729-742.

X-radiography and autoradiography of thin vertical sections were used to estimate growth rate of *Favites virens* from Bikini Lagoon. Discrete bands of radioactivity were identifiable with specific nuclear test series (1954, 1956, 1958). The coral growth rate of 8.0 mm/year is in good agreement with rate derived from the "seasonal" alternating light and dark bands on X-radiographs. With these bands as growth rate indicators, the coral was sectioned into yearly increments and analyzed to reconstruct variations in concentration of transuranics (Am-241, Pu-238,-239,-240,-241) and other radionuclides (Sr-90, Y-90, Cs-137, Rh-102m, Sb-125, Eu-155, Bi-207, Co-60, Po-210, Pb-210) in the marine environment at Bikini since 1954. From concentration data retained in this indicator species, exchange rate of radionuclides between lagoon and open ocean is computed to be longer than exchange rates based on physical circulation data. There is no constant ratio of plutonium isotopes in the coral growth sections. The Pu-240:Pu-239 activity ratios in coral average 0.77; this ratio decreasing in each post-test year to 72% of its test year value, and in 1960 increasing to 20% over the post-test series year. The average Pu-238:Pu-239, Pu-240 ratio was 0.040 for 1969-1972. This suggests that redistributions of the several plutonium isotopes in the environment may be governed by different biogeochemical processes.

Stable strontium in coral averaged 8.94 mg/g. The concentration factors for Pu-239,-240 and Sr-90 in Bikini coral are 2.7 x 10^3 and 1.1 x 10^3, respectively. These values are very similar to water concentration values, indicating that coral species take up Sr-90 and Pu-239,-240 in proportion to environmental concentrations.

The following activity ratios were found in recent coral sections: Am-241:Eu-155, 0.83; Co-60:Eu-155, 4.4; and Bi-207:Eu-155, 1.0. The concentration of Po-210 (Pb-210) in coral from 1966-1971 was 0.20 pCi/g. There was a small but definite increase during test years, which correlates with an increase in artificial radionuclides. This contradicts previous arguments that no Pb-210 has resulted from weapons testing.

1928. Nuorteva, P. and E. Hasanen. 1975. Bioaccumulation of mercury in *Myoxocephalus quadricornis* (L.) (Teleostei, Cottidae) in an unpolluted area of the Baltic. Ann. Zool. Fennici 12: 247-254.

In the unpolluted Bromary area of the Baltic, mean mercury content was 0.03 mg/kg wet wt for invertebrates, 0.10 mg/kg in flesh of fishes that feed on invertebrates, 0.29 mg/kg in flesh of piscivorous fishes, and 0.35 mg/kg in flesh of fish-eating migratory birds. Mercury content of the stenothermal fish *Myoxocephalus quadricornis* increased with size to a maximum value of 0.47 mg/kg. Observations from an area moderately polluted with mercury showed a notably accelerated accumulation of mercury, which was evident from the increased slope of the regression line of mercury content on body size. This and earlier observations indicate that the balanced natural condition of mercury circulation is characterized by regression coefficients near zero. Mercury contents of other invertebrate-eating fishes living in the same environment at Bromary were below the suggested maximum background level of 0.2 mg/kg. The exceptionally strong bioaccumulation of mercury in *M. quadricornis* is probably a result of its feeding on mysidaceans which have a higher mercury content (0.06-0.09 mg/kg) than other invertebrates (0.01-0.03 mg/kg). The transfer of such peak concentrations along the food chain is possible only in oligotrophic conditions, where there are relatively few species and each predator has a limited spectrum of prey animals.

1929. Nuorteva, P. E. Hasanen, and S.-L. Nuorteva. 1975. The effectiveness of the Finnish anti-mercury measurements in the moderately polluted area of Hameenkyro. Ymparisto ja Terveys 6(8):611-635. (English summary)

Measures were taken in 1967 to end Hg pollution and reduce the population's intake of Hg in Finland. Four to 8 years later (1971-1975) Hg content of fish, in mg/kg, from waters above source of pollution ranged from 0.19 to 0.42. At locations going increasingly downstream from source, ranges of Hg concentrations decreased from 0.95 to about 0.59 mg/kg. Decrease of Hg content in pikes from 1971 to 1975 averaged 0.2 mg/kg/yr. An average of 12.9 mg/kg Hg was found in hair of persons consuming fish. Persons eating little or no fish had 1.5 to 2.6 mg/kg Hg in their hair; the current tolerance limit is 6 mg/kg.

Blowflies (sarcophagous flies of family Calliphoridae) were tested for possible value as indicators of degree of Hg contamination in the environment. Hg content of flies rises in positive correlation to mercury content of feeding substrates, but has only a 2 day half-life in flies. This decreases considerably when flies turn to a carbohydrate diet before period of egg development.

1930. Oglesby, L.M. and A.C. Bannister. 1959. Sodium and potassium in salt-water fish. Jour. Amer. Dietet. Assoc. 35:1163-1164.

Sodium content in 9 species of Gulf Coast saltwater fishes ranged from 468 to 1,012 mg/kg wet wt whole fish with an average of 661 mg/kg. Potassium content ranged from 1,911 to 3,230 mg/kg wet wt whole fish with an average of 2,411. These values are comparable to fish from other geographical areas and are suitable for use in sodium-restricted diets.

1931. Ogura, K. 1959. Midgut gland cells accumulating iron or copper in the crayfish, Procambarus clarkii. Annotationes Zoologicae Japonenses. 32:133-142.

Accumulation of ferric iron and copper under natural conditions was detected in midgut gland. Both metals appeared in a particular type of acinus cells, being contained in various size granules. Besides iron or copper-containing cells, a few other types of cells were distinguished in acinus epithelium. Excretion of metal-containing granules was markedly promoted by removal of eyestalks.

1932. Oguri, M. 1976. On the enlarged liver in "cobalt" variant of rainbow trout. Bull. Jap. Soc. Sci. Fish. 42(8):823-830.

Trout from high cobalt environments were characterized by corpulent body structures and enlarged livers. Liver in fish weighing 40 to 60 g contained elevated glycogen levels; liver of larger trout contained abundant fat droplets. It was concluded that liver enlargement in trout from high cobalt waters was induced by accumulation of glycogen and fat resulting from organ malfunction.

1933. Ohmomo, Y., H. Suzuki, M. Sumiya and M. Saiki. 1972. Studies on accumulation, excretion and distribution of iodine-131 and cadmium-115m in freshwater fish and marine fish. Jour. Rad. Res. 13:3-4. (Abstract)

High accumulation of cadmium-115m in kidney was noted in the freshwater teleost *Cyprinus carpio*; in the marine fish *Girella punctata*, highest enrichment was in digestive tract. High excretion range of cadmium-115m from gill was recognized for both *Cyprinus* and *Girella*. The longest-lived component of cadmium-115m in freshwater fish had a biological half-life of about 58 days.

1934. Okubo, K. and T. Okubo. 1962. Study on the bioassay method for the evaluation of water pollution - II Use of the fertilized eggs of sea urchins and bivalves. Bull. Tokai Reg. Fish. Res. Lab. 32:131-140. (In Japanese, English summary)

Concentrations of metals salts, which grossly affect larval development (no effect on development) of sea urchin *Anthocidaris*, sea urchin *Hemicentratus*, mussel *Mytilus*, and oyster *Crassostrea*, in 24 hr at 20-27 C were determined. Concentrations in mg metal/l for Cu were 0.1 (0.032), 0.032 (0.01), 0.1 (0.032) and 0.1 (0.032); for Hg this was 0.032 (0.01) for all 4 species; for Fe, 10 (3.2), n.d., 32 (10), and n.d.; for Mn 32 (10), n.d., 32 (10) and n.d.; for Zn 0.32 (0.1), n.d., 1.0 (0.32) and 3.2 (1.0); and for Cr 10 (3.2), >1.0, 10 (3.2) and n.d., respectively. LC-50 (24 h) values, in mg/l for brine shrimp *Artemia*, were 0.68 to 2.5 for Cu, 21 to 50 for Hg, 1570 to 2880 for Mn, 160 to 275 for Zn and 40 for Cr. LC-50 (24 h) values, in mg/l, for crabs *Sesarma*, were 5.2 to 6.0 for Cu, 0.06 for Hg, 500 for Mn, 6.2 for Zn and 56 for Cr. Respective levels of no effect for barnacle *Balanus* adults and nauplii, respectively, were, in mg/l: 3.2 and 3.2 for Cu; 0.32 and 0.1 for Hg; 100 and 100 for Mn; 32 and 3.2 for Zn; and 3.2 and n.d. for Cr. Authors concluded that larval stages were more sensitive to metal pollutants than previously examined adult forms.

1935. Olafson, R.W. and J.A.J. Thompson. 1974. Isolation of heavy metal binding proteins from marine vertebrates. Marine Biology 28:83-86.

Cadmium binding proteins have been isolated from liver homogenates of the Atlantic grey seal *Halichoerus grypus*, the Pacific fur seal *Callorhinus arsinus*, and copper rock fish *Sebastodes caurinus*. Rock fish showed an increase in hepatic cadmium binding protein upon administration of $CdCl_2$. The apparent molecular weights of the isolated proteins were 9000 for grey seal, 10,000 for fur seal, and 11,000 for fish.

1936. Olson, G.F., D.I. Mount, V.M. Snarski and T.W. Thorslund. 1975. Mercury residues in fathead minnows, *Pimephales promelas*

Rafinesque, chronically exposed to methylmercury in water. Bull. Environ. Contamin. Toxicol. 14(2):129-134.

Minnows were continuously exposed to methylmercury water concentrations of 0.018, 0.036, 0.063, 0.114, and 0.247 ug/l. After 48 weeks exposure total mercury residues in whole fish were 1.47, 2.50, 4.48, 7.06, and 10.90 mg Hg/kg tissue (wet wt). Concentration factors for lowest and highest water concentrations were 8.2 x 10^4 and 4.4 x 10^4, respectively. Control fish living in water with concentrations of mercury less than 0.01 ug/l contained 0.21 mg/kg total body residue. These body concentrations are the result of continuous water exposure and probable intake from a portion of the food eaten.

1937. Olson, K.R. and R.C. Harrel. 1973. Effect of salinity on acute toxicity of mercury, copper, and chromium for *Rangia cuneata* (Pelecypoda, Mactridae). Contrib. Mar. Sci. 17:9-13.

The 48, 72, and 96 hr LC-50's for mercury, copper, and chromium were determined for a brackish water clam at salinities of <1°/oo, 5.5°/oo, and 22°/oo. All ions were more toxic in freshwater than in more saline waters requiring 6.3 mg/l Hg, 0.78 mg/l Cu, and 0.96 mg/l Cr for a 48 hr LC-50. At 5.5°/oo, 48 hr LC-50's were 40.0 mg/l Hg, 16.0 mg/l Cu, and 66.0 mg/l Cr; and at 22°/oo, 48 hr LC-50's were 17.0 mg/l Hg, 14.7 mg/l Cu, and 86.0 mg/l Cr. Seventy-two and 96 hr LC-50's followed similar trends.

1938. Ophel, I.L. and J.M. Judd. 1967. Skeletal distribution of strontium and calcium and strontium/calcium ratios in several species of fish. *In* Lenihan, J.M.A. (ed.). Strontium metabolism. Academic Press: 103-109.

Sr and Ca contents of bony and calcified structures of perch *Perca flavescens*, from Perch Lake, Canada, and Lake Huron and redhorse sucker *Moxostoma areolum* from Lake Huron were determined. The Ca content in mg/g ash wt, was uniform in different bony tissues of the same fish; this ranged from 362 to 372 in Perch Lake perch, 364 to 371 in Lake Huron perch and 327 to 367 in Lake Huron suckers. Each species had a characteristic Sr content: values in mg/kg ash wt ranged from 373 to 413 in Perch Lake perch, 272 to 312 in Lake Huron perch and 321 to 389 in Lake Huron sucker. Differences in Sr content in bone of perch from the two lakes reflect differences in Sr/Ca ratios of lake waters. Observed strontium/calcium ratios (Sr/Ca in fish bone to Sr/Ca in lake water) in Perch Lake perch was 0.21. In Lake Huron fish, these ratios were for perch 0.19, redhorse sucker 0.23, longnose sucker *Catostomus catostomus* 0.23, gizzard shad *Dorosoma cepedianum* 0.24, and carp *Cyprinus carpio* 0.66. Authors concluded that high observed ratio in carp is due in part to its diet of aquatic plants which do not discriminate against Sr.

1939. Oporowska, K. 1976. Investigations on the content of copper in the ponds of some regions of Poland. Acta Hydrobiol. 18(2): 139-152.

Cu and Zn levels in fish from eleven Polish ponds were determined. Cu levels in gills, in mg/kg wet wt, ranged from 2.5 (tench) to 11.7 (German carp). Zn in gill ranged from 4.8 (tench) to 44.0 (carp). For liver, Cu levels extended from 5.2 (pike) to 18.5 (carp); Zn range was 6.0 (pike) to 29.5 (carp). In flesh, Cu content ranged from 1.2 (carp) to 1.7 (tench); for Zn this was 1.1 (pike) to 4.2 (carp). Copper in water column for all ponds ranged from 1-490 μg/l; for bottom sediments this was 8-535 mg/kg dry wt. High Cu in water and sediments was reflected in high Cu content of fish gills.

1940. Orvini, E., T.E. Gills and P.D. LaFleur. 1974. Method for determination of selenium, arsenic, zinc, cadmium, and mercury in environmental matrices by neutron activation analysis. Anal. Chem. 46:1294-1297.

Average concentrations, in mg/kg wet wt, for albacore tuna flesh were: Se 3.3, As 4.6, Zn 13.4, Cd 0.06, and Hg 1.03.

1941. Oshida, P.S., A.J. Mearns, D.J. Reish and C.S. Word. 1976. The effects of hexavalent and trivalent chromium on Neanthes arenaceodentata (Polychaeta: Annelida). S. Calif. Coastal Water Research Project, 1500 E. Imperial Hwy., El Segundo, Calif., TM 225. 58 pp.

Lethal and sublethal effects of Cr^{+3} and Cr^{+6} upon marine polychaetes were evaluated. For hexavalent chromium, as $K_2Cr_2O_7$, the LC-50 (96 hr) and LC-50 (168 hr) value ranges were 2.2 to 4.3, and 1.44 to 1.89 mg Cr^{+6}/l. In a long-term (3 generations, 440 days) experiment with Cr^{+6}, reproduction ceased at 0.10 mg/l and brood size decreased at levels of 0.0125 mg/l and above. Worms exposed to 0.05 mg/l Cr^{+6} in the long-term experiment had tissue concentrations of 6.20 to 81.7 mg/Cr kg wet wt, which is more than 10X greater than controls (0.486 to 1.55 mg/wet kg) exposed to <0.001 mg/l total Cr. In experiments with trivalent chromium (as $CrCl_3$), in which worms were exposed to a precipitated form of Cr^{+3}, there was <5% mortality at 12.5 mg/l during a period of 168 hr. Worms that lived in Cr^{+3} precipitate during a long-term (2 generations, 293 days) experiment showed no adverse effects or abnormal behavior. Thus, although Cr^{+6} reduces brood sizes at relatively low seawater concentrations (0.0125 mg/l), Cr^{+3} as a precipitate in seawater had no detrimental effects on worms at concentrations of 50.4 mg/l. A literature review of Cr in the environment, wastewater and invertebrates, as well as effects of selected trace metals on polychaetes, is presented.

1942. Oshida, P. and D.J. Reish. 1975. Effects of chromium on reproduction in polychaetes. So. Calif. Coastal Water Res. Proj., 1500 E. Imperial Hwy., El Segundo, Calif. Ann. Report: 55-60.

Hexavalent and trivalent chromium effects on *Nereis arenaceodentata* at various concentration levels were determined. At 20 C, lethal levels of Cr^{+6} were 2.22 to 4.30 mg/l in 4 days, from 1.44 to 1.89 in 7 days, 0.78 in 14 days, and 0.2 mg/l in 56 days. The lowest level inhibiting tube building was 0.079 mg/l in 14 days. For Cr^{+3}, no significant mortality occurred at 0.195 to 12.5 mg/l levels over a 3 week period; total die-off occurred at 50 mg/l within 24 hr, probably from extremely low pH (4.5). Inhibition of egg laying occurred at 0.1 and 0.2 mg/l Cr^{+6}; abnormal behavior occurred only at 0.2 mg/l level. Presence of Cr^{+6} caused reduction in mean brood size from 305 in controls to 150 at 0.0125 mg/l, 137 at 0.025 mg/l, and to 78 at 0.050 mg/l. Relative mean times required to spawn were longer in controls (117 d) and 0.05 mg/l (121 d) than in 2 intermediate concentrations of 0.0125 mg/l (107 d) and 0.025 mg/l (90 d). Reduced spawning time implies a net increase in number of generations per year and therefore larger populations for animals exposed to intermediate Cr concentrations. Trivalent Cr showed no significant mortality prior to spawning or abnormal behavior. Data suggest that pure trivalent Cr in seawater forms a precipitate that is not toxic to *N. arenaceodentata*.

1943. Osterberg, C. 1962. Fallout radionuclides in euphausiids. Science 138:529-530.

Euphausia pacifica, collected off the western U.S. coast, contained up to 618 pCi Zr-95-Nb-95, 180 pCi Ce-141, and 30 pCi Ru-103 per g dry wt. Values were highly variable both temporally and spatially.

1944. Osterberg, C., A.G. Carey and H. Curl. 1963. Acceleration of sinking rates of radionuclides in the ocean. Nature, London 200:1276-1277.

Sea cucumbers *Paelopatides* sp. collected from a depth of 2800 m contained Ce-141-144, Zr-95-Nb-95 and K-40 in amounts similar to those of *Stichopus californicus*, a sea cucumber from 200 m. Amounts of Zn-65 in *Paelopatides* was lower than that of *Stichopus*. Sea anemones and worms from 2800 m also contained Zr-95-Nb-95. Authors suggest that short (7-12 d) downward transit times of Zr-95-Nb-95 and Ge-141-144 are due to incorporation of unassimilated radionuclides in fecal pellets of copepods, euphasiids, salps and pteropods.

1945. Osterberg, C., L. Small and L. Hubbard. 1963. Radioactivity in large marine plankton as a function of surface area. Nature, London 197:883-884.

Euphausia pacifica of mean length 20 mm were compared with copepods *Calanus cristatus*, averaging about 9-10 mm in content of K-40, Zn-65, Zr-95-Nb-95, Ru-103-106, Cr-51 and Ce-141. Total radioactivity per gram dry wt was greater in euphasiids despite their smaller surface area per unit wt. A second experiment comparing large adult *E. pacifica* with small adults and juveniles showed that radioactivity, with exception of Cr-51, was not greater in small euphasiids, which exhibited greater surface area per unit wt ratios and indicates that factors other than surface area are important. The exception of Cr-51 may be significant due to particle size of Cr. A comparison of radioactivity in the transparent outer body of pelagic tunicates *Salpa* sp., with internal "nucleus" which contains digestive tract, showed higher concentrations in nucleus. Zirconium-95-niobium-95, and cerium-141 which are particulate in seawater were most strongly concentrated in the "nucleus" while zinc-65 and potassium-40, which are in ionic form show markedly smaller concentration ratios.

1946. Ottolenghi, P. 1975. The reversible delipidation of a solubilized sodium-plus-potassium ion-dependent adenosine triphosphatase from the salt gland of the spiny dogfish. Biochem. Jour. 151:61-66.

A microsomal fraction rich in Na^+, K^+-ATPase and corresponding K^+-dependent p-nitrophenyl phosphatase from rectal salt gland of spiny dogfish *Squalus acanthias*, was solubilized by treatment with deoxycholate at high ionic strength. On gel filtration, the ATPase apoenzyme could be separated in apparently soluble form, from the tissue-fraction phospholipids and was almost free of enzymic activity. On mixing the apoenzyme with an activator, a large proportion of the original enzymic activity was obtained. Specific activities of the re-activated enzyme were somewhat higher than in the material before gel filtration: values of 1300-1450 uM and 250-290 uM/h per mg of protein were obtained for the hydrolysis of ATP and of p-nitrophenyl phosphate,respectively. The activity was inhibitible by ouabain.

1947. Overnell, J. 1975. The effect of heavy metals on photosynthesis and loss of cell potassium in two species of marine algae, Dunaliella tertiolecta and Phaeodactylum tricornutum. Marine Biology 29:99-103.

For D. tertiolecta, Cu-induced K release occurred at marginally lower concentrations than did inhibition of photosynthesis; the primary toxic effect of Cu being an increase in permeability of the cell. Mercury and thallium appear to be transported through the outer membrane of cell to chloroplast where photosynthesis is inactivated at concentrations causing no damage to cell membrane, as reflected in K leakage. Methyl Hg had a very limited effect on K leakage, suggesting a very selective action on the membrane. Methyl Hg caused complete inhibition of oxygen evolution at low levels ($\sim 1 \times 10^{-6}$ M). P. tricornutum was particularly sensitive to external K concentrations. At Hg or Cu concentrations above 10^{-5} M, light-induced respiration occurred. This may be due to decomposition of chloroplast lamellae, with subsequent liberation of chlorophyll forms capable of promoting photosynthesized oxidation of reducible substrates present in cells. Both algal species were insensitive to Cd, Pb and Zn.

1948. Palermo, T. 1971. Analysis of fish tissue for mercury content. State of Mass. Div. Fish Game, Proj. F-35-R-3, Job III-1. 10 pp.

A total of 59 fish collected between July 1970 and March 1971 from 11 freshwater streams and 16 ponds in Massachusetts were analyzed for total mercury. Stream-caught fish (n=24) contained between 0.03 and 0.99 mg Hg/kg wet wt muscle, with 33% at or above the FDA level of 0.5 mg/kg. Pond-caught fish (n=35) contained between 0.05 and 1.36 mg Hg/kg wet wt muscle, with 40% at or above the established 0.5 mg/kg level. Most fish containing more than 0.5 mg Hg/kg wet wt were predators, i.e. walleye, largemouth bass, smallmouth bass, and chain pickerel. A total of 22 trout (brook, brown and rainbow) from 4 hatcheries were also analyzed for mercury. Concentrations of Hg in catchable-size hatchery trout ranged from 0.00 to 0.10 mg/kg wet wt muscle.

1949. Parrish, K.M. and R.A. Carr. 1976. Transport of mercury through a laboratory two-level marine food chain. Marine Poll. Bull 7(5):90-91.

Algae Croomonas salina, grown in 164 μg Hg/l for 48 hrs, accumulated 1400 mg Hg/kg dry wt. Copepods Acartia tonsa, fed contaminated C. salina for 5 days showed no impairment of egg laying, nor retention of Hg in tissues, eggs or feces. Eggs of an exposed female developed to the copepodite IV stage with no apparent ill effects.

1950. Parry, G. 1954. Ionic regulation in the palaemonid prawn *Palaemon* (=*Leander*) *serratus*. Jour. Exp. Biol. 31:601-613.

Blood and urine of *Palaemon serratus* were analyzed for Na, K, Ca, Mg, Cl, and SO_4 during immersion in 50, 100 and 120% seawater. In 100% SW concentrations, expressed as percentages of concentrations in medium, were: Na, K and Cl, 85%; Ca, 105%; Mg, 20%; SO_4, 10%. In 50% SW the corresponding figures were: Na and Cl, 105%; K, 120%; Ca, 200%; Mg, 20%; SO_4, 10%. In 120% SW these values were: Na, K and Cl, 85%; Ca, 115%; Mg, 30%; SO_4, 20%. Concentrations of Na, K and Ca in urine are always slightly (≤20%) less than concentrations in blood; Cl level is slightly greater in urine than blood (10-20%) and concentrations of Mg and SO_4 are very much greater, by factors of up to 7 times. Relative concentrations of ions in blood and urine do not change substantially with changes in external medium. The antennal gland, although it plays no part in purely osmotic regulation, is partly responsible for maintaining low blood concentrations of Mg and SO_4.

1951. Parry, G. 1957. Osmoregulation in some freshwater prawns. Jour. Exp. Biol. 34:417-423.

The salt concentration in blood and urine of *Palaemonetes antennarius*, a freshwater prawn, was different than the brackish water *P. varians* and *Palaemon longirostus*. Contrary to freshwater crayfish which produce dilute urines, *P. antennarius* produces urine isosmotic with blood at the rapid rate of 2% body wt/hr. When held in distilled water these prawns lost salt at a rate of 2.21 uM/g/hr; upon return to natural (very dilute) medium, an uptake rate of 2.56 uM/g/hr was observed. It is probable that under natural conditions there is a constant absorption of ions to compensate for osmotic inflow of water and loss of salts through antennal glands.

1952. Parry, G. and W.T.W. Potts. 1965. Sodium balance in the freshwater prawn, *Palaemonetes antennarius*. Jour. Exp. Biol. 42: 415-421.

Sodium content of *P. antennarius* and rates of influx and efflux in freshwater and other media are described. The greater part of efflux is due to loss in urine. Loss varies from 3.5 mM-Na/kg animal/hr (79.5 mg Na/kg/hr) to 4.3 mM/kg/hr (98.9 mg/kg/hr) depending on media. Rate of influx depends on salt load of the animal: salt-deficient animals have a higher uptake rate than equilibrated animals; salt-loaded animals have lower rates of uptake. Influx rate declines rapidly at external salinity <0.5 mM/l, while efflux remains almost constant. This could indicate a threshold effect and may be important in determining distribution of *P. antennarius*

1953. Pasanen, S. and P. Koskela. 1974. Seasonal changes in calcium, magnesium, copper and zinc content in the liver of the common frog, Rana temporaria L. Comp. Biochem. Physiol. 48A:27-36.

In Finland, values in frog liver for Ca, Mg, Cu and Zn per unit wt are lowest during winter and highest during spring and summer, partly as a result of seasonal changes in wt and water content of liver. The total Ca, Mg, and Zn figures are highest during summer and autumn due to feeding and rapid metabolism. Total copper remains practically constant throughout the year in liver of males, but in females there is a clear spring maximum connected with egg-laying. Sex differences are found in dry wt liver Ca and Mg content during summer, apparently due to ovary development. Highest values recorded, in mg/kg dry wt, were 315 for Ca, 749 for Mg, 845 for Cu, and 91 for Zn. On a wet wt basis these were 75 for Ca, 180 for Mg, 207 for Cu, and 25 for Zn.

1954. Patel, B. and G.R. Doshi. 1971. Lamellidens marginalis (Lamarck) as indicator of ^{54}Mn. Arch. Oceanogr. Limnol. 17:27-42.

During radioecological studies in Bombay, the freshwater mussel L. marginalis concentrated high amounts of Mn-54 deposited through fallout, and stable manganese from its environment. Teleosts (Labeo rohita, Cyprinus carpio, Tilapia mossambica) from the lake contained background levels of Mn-54. Of the various tissues of mussel, labial palp showed maximum concentration of stable (9872 mg/kg) and radioactive (∿9000 pc Mn-54/kg) manganese, followed by gill, mantle fold, visceral sac, adductor muscle and foot. Concentration factors, in mg/kg wet wt, were determined for Mn (1122 x 10^2), Zn (258 x 10^2), Fe (4 x 10^2), Cu (16 x 10^2), Sr (32 x 10^2) and Ca (16 x 10^2). Distribution of Mn, Ca, and Sr in various parts of shell are also given.

1955. Patel, B. and A.K. Ganguly. 1968. Concept of acute and chronic tissue concentration of elements in radioecology. Symp. on Mollusca, Marine Biol. Assn. India, Vol. 2:446-455.

Using data from previous studies, authors differentiate two types of concentration and concentration factors encountered in radioecological studies: one obtained under natural environmental conditions; and another under controlled laboratory conditions and using the Chronic Concentration (CC), Chronic Concentration Factor (CCf), Acute Concentration (AC), and Acute Concentration Factor (ACf).

For metabolically significant trace elements, such as Zn, Mn, Fe, Co, etc., which form parts of enzymes systems, CCf's are consistently higher than ACf's in all marine organisms studied. Curves of uptake and elimination rates for these elements by shellfish are always steeper for uptake than initial loss rates. Elements with chemical properties similar to the previous ones, but whose metabolic functions/importance are not known, such as Ce, Sr, etc., have ACf's and CCf's which are often the same in soft tissues; rate of uptake depending on relative concentration of chemically similar elements in the medium. CCf's of Sr are higher than ACf's in skeletons of invertebrates and fish, possibly due to fixation of minerals in the non-metabolic zone of skeletal system. Uptake and elimination rate curves for these elements have both steep uptake and initial elimination rates, with slopes very close to one another. For elements which are metabolically not significant, such as Cr, U, Pu, etc., AC's and CC's depend on concentration of element in medium. In general, CCf's are higher than ACf's for both Cr and U. Definite conclusions on Pu cannot be drawn as equilibrium with Pu may not be attained in the orgamism's lifetime. These elements show a lower initial rate of absorption than elimination in uptake-elimination rate curves. Organisms, in general, concentrate significantly higher amounts of isotopes under chronic exposure conditions than acute exposure. Lifetime exposure to a radioisotope under natural conditions eventually results in CCf's of the same value as those obtained with stable isotopes in the environment.

1956. Patel, B., C.D. Mulay, and A.K. Ganguly. 1975. Radioecology of Bombay Harbour—a tidal estuary. Estuarine Coast. Marine Sci. 3:13-42.

Low level liquid radioactive wastes from nuclear facilities at Bhabha Atomic Research Centre, Bombay, are released into Bombay Harbour after monitoring and dilution. Interactions of gamma-emitting fission product nuclides, especially cesium-137, with sedimentary particles and biota were studied during 1968-71. Cesium-137 is first scavenged by sedimentary particles, followed by cerium-144 and ruthenium-106. Zirconium/niobium-95, though present in the effluent, was not sorbed. Cs-137 was distributed throughout the harbor, whereas Ce and Ru deposition were limited to a few stations off Trombay coast. Maximum deposition of Cs-137 activity was around the discharge zone off Trombay; it decreased significantly with distance, the concentration being 100X lower towards the harbor mouth. Over the period of surveillance there was about 2-3X increase in accumulation of radioactivity by bed material, though total radioactivity in effluent discharge had increased 5X. Maximum deposition of activity was found in the upper 5 cm layer of sediment column; decreasing thereafter either intermittently or exponentially with depth. The sorption sequence of Cs-137, Ce-144 and Ru-106 was explained in terms of sorption rate, mineral structure, and physicochemical parameters controlling diffusion mechanisms.

The occurrence of artificial radioactivity in fish and shellfish of economic importance in 1965 before regular discharge began was below the detection limit. Anlaysis since then showed accumulation of Cs-137 only. Other nuclides, Ce-144, Ru-106 and Zr/Nb-95, were not detected except in the ark-shell bivalve Anadara granosa, which showed specific accumulation of Cs, Ce, and Ru nuclides but not Zr/Nb-95, although this nuclide was present in the effluent. A. granosa was therefore used as an indicator to detect contamination due to cerium and ruthenium radionuclides. Lamellibranchs and crustaceans, in general, were the most effective integrators of Cs-137. In these benthic species, concentration factors (Cf's) for the nuclide varied from 10^2 to 10^5; pelagic species were poor integrators of Cs-137 (Cf's: 10-50). Monthly variation in concentration of Cs-137 in A. granosa, Placenta placenta (bivalve), Scylla serrata (crab), and Periopthalmus sp. (fish) could be related to variation in amount of activity released. Maximum concentration of Cs-137 occurred in muscle tissues of different species. Radiation dose from contaminated environments to benthic communities was far below limits required to produce detectable radiation damage. Radiation dose to fishermen, both internally through the consumption of contaminated marine products and externally through fishing over the contaminated bed, was also well below permissible dose limits.

1957. Patrick, F.M. and M. Loutit. 1976. Passage of metals in effluents, through bacteria to higher organisms. Water Research 10:333-335.

Bacteria were most abundant in river sediments receiving effluents from various sources. Sediment isolates contained metal levels, in mg/kg dry wt, of 2973 for Cr, 1512 for Cu, 456 for Mn, 2664 for Fe, 1881 for Pb, and 1127 for Zn when grown in 2 mg of each metal/l for 7 days at 28 C. Tubificid worms of genera Tubifex and Limnodrilus, from stream sediments contained concentrations, in mg/kg dry wt, of 19 for Cr, 81 for Cu, 113 for Mn, 1286 for Fe, 151 for Pb, and 530 for Zn. Worms fed bacterial cells grown in 2 mg/l of each metal contained levels, in mg/kg dry wt, of 30 for Cr, 621 for Cu, 25 for Mn, 1944 for Fe, 568 for Pb, and 868 for Zn.

1958. Peakall, D.B., D.S. Miller and W.B. Kinter. 1975. Blood calcium levels and the mechanism of DDE-induced eggshell thinning. Environ. Pollut. 9:289-294.

Ring doves Streptopelia risoria, and white Pekin ducks Anas platyrhynchos, fed DDE, exhibited 35% and 20% eggshell thinning, respectively; blood calcium levels remained constant at 20 and 46 mg %, respectively. Blood calcium levels, although constant in ring doves, are more variable in ducks, decreasing to 18 mg % when not laying. Results from these studies are consistent with those mechanisms of DDE action involving inhibition of shell gland function, but not with those involving decreased calcium supply to the gland.

1959. Pelati, L.T. and C. Triulzi. 1972. The radioactivity of some plankton and sea water samples collected during the 1960-1968 period. Rapp. Comm. int. Mer Medit. 20:735-737.

Gross beta radioactivity in plankton, including activity contributed by Ce-144, Pm-147, Eu-155, Zr-95, Sb-125, and Mn-54, was measured from the North Adriatic and Ligurian-Tyrrhenian Seas during 1960-1968. Highest values were reached in 1963 and these approximated the trends of fallout debris; in 1968 the same values of 1961 were reached. Comparison of Sr-90 values in seawater and plankton samples for North Adriatic and Ligurian-Tyrrhenian Seas showed that Sr-90 contamination of seawater is higher in the Adriatic while Sr-90 contamination of plankton is always higher in Ligurian-Tyrrhenian Sea. Concentration factors for plankton samples are 10X more for Ligurian-Tyrrhenian plankton than Adriatic plankton; this was attributed to presence of the protozoan Acantharia, as specific strontium accumulators.

1960. Penot, M. and C. Videau. 1975. Absorption du ^{86}Rb et du ^{99}Mo par deux algues marines: Le Laminaria digitata et le Fucus serratus. Z. Pflanzenphysiol. Bd. 76 (Suppl):285-293.

During exposure for 2 hrs in seawater containing rubidium-86 at 15 C, Fucus accumulated the equivalent of 1.7 mg/kg Rb dry wt; for Laminaria this was 1.0. Similar studies with molybdenum-99 showed Laminaria with 0.5 mg/kg Mo dry wt, but only 0.1 mg/kg in Fucus during an identical exposure interval. Temperature affects uptake of Rb by Laminaria; Rb content at 15 C was twice that at 0 C in 2 hr. Fucus accumulated 2X more Mo at 15 than 0 C in 5½ hrs. Rb uptake by Fucus was reduced by half in 5 hrs with 10^{-3} M dinitrophenol; a similar pattern was observed with Mo uptake by Laminaria and 10^{-5} M KCN. Increasing light intensity (lux) enhances Rb uptake in both species; however, light intensity did not effect Mo uptake by either in 5 hrs.

1961. Penrose, W.R. 1975. Biosynthesis of organic arsenic compounds in brown trout (Salmo trutta). Jour. Fish. Res. Bd. Canada 32:2385-2390.

Radioactive inorganic arsenic was administered to trout orally and by intramuscular injection. After oral administration of 1 μg As as arsenic acid, As concentrations in μg/kg, in blood, muscle and liver tissues after 4.5 hr were, respectively, 0.20, 0.18 and 1.08; after 24 hr, these were 0.37, 2.03 and 1.42. Uptake of orally administered As was accompanied by conversion to a nonanionic form, which was also found in gastro-intestinal contents. Following IM injection of 1 μg As as arsenic acid, As concentrations after 4.5 hr, in μg/kg in blood, muscle and liver tissues of trout were 6.67, 1.10 and 2.80, respectively; after

48 hr, these were 0.13, 1.37 and 0.76. Injected As appeared in tissues in inorganic form and was only slowly converted to organic form; meanwhile, large amounts of inorganic and organic As occurred in bile. Author maintains that findings are consistent with biosynthesis of organic As compound within gastro-intestinal tract.

1962. Penrose, W.R., R. Black and M.J. Hayward. 1975. Limited arsenic dispersion in seawater, sediments, and biota near a continuous source. Jour. Fish. Res. Bd. Canada 32:1275-1281.

Moreton's Harbor, Newfoundland, has been exposed to arsenic-bearing drainage and leaching from a stibnite mine for at least 38 years. Sediments contained 2600 mg As/kg at point of input, 847 mg/kg 34 m offshore and 11.0 mg As/kg 65 m offshore. Inorganic As levels in seawater were 5.3, 4.1, 2.4 and 0.2 μg/l at distances of 0, 34, 147 and 186 m, respectively. Sea urchin *Strongylocentrotus droebachiensis* gonads contained As levels, in mg/kg, of 6.0, 5.6, 3.8 and 1.9 at distances of 0, 35, 57 and 189 m from input source. Respective As levels, in mg/kg, of marine organisms collected at source of As input, and from control sites 5 or 300 km distant, were 5.3 and 1.6 for mussel *Mytilus edulis* (minus shell); 11.5 and 4.0 for snail *Littorina littorea* (minus shell); 17.2 and 12.1 for algae *Fucus* sp.; 17.2 and 9.8 for algae *Ascophyllum nodosum*; and 0.8 and 0.4 for blenny (fish) muscle. Lobsters *Homarus americanus*, collected at input site, contained 3.8 and 7.6 mg As/kg.

1963. Pentreath, R.J. 1971. The metabolism of radio nuclides. *In* Marine Radioecology, Proc. Second ENEA Seminar, Hamburg: 97-126.

Author reviews radionuclide metabolism processes in freshwater and marine biota, including effects of temperature and salinity on uptake, retention, excretion, tissue distribution and storage, subcellular distribution, enzyme utilization and dynamics of cellular exchange. Specific examples are given with isotopes of Ce, Cs, Ca, Sr, Zn, Ru, Nb, K, Y, Fe, Mn, and Co in algae, crustacea, teleosts, molluscs, annelids, and elasmobranchs.

1964. Pentreath, R.J. 1973. The accumulation from seawater of ^{65}Zn, ^{54}Mn, ^{58}Co and ^{59}Fe by the thornback ray, *Raja clavata* L. Jour. Exp. Mar. Biol. Ecol. 12:327-334.

Respective Zn, Mn and Fe concentrations, in mg/kg wet wt, of thornback rays, were 4.7, 0.16 and 105 for whole blood; 9.4, 0.27, and 29 for heart; 15.9, 0.32 and 109 for spleen; 17.1, 1.45 and 62 for liver; 11.3, 1.95 and 33 for kidney; 10.9, 0.37 and 9 for gonad; 14.8, 0.82 and

13 for gut; 11.1, 1.47 and 24 for gill filaments; 12.3, 2.73 and 9 for skin; 4.8, 0.29 and 2 for muscle; 19.3, 9.12 and 5 for cartilage; 8.5, 1.07 and 34 for rectal gland; and 10.1, 0.41 and 10 for brain and nerve cord, giving whole body levels of 9.6 (Zn), 2.4 (Mn), and 9.4 (Fe). After 90 days, whole body concentration factors were 20, 5, 3 and 1 for Fe-59, Zn-65, Co-58 and Mn-54, respectively.

1965. Pentreath, R.J. 1976. Some further studies on the accumulation and retention of Zn-65 and Mn-54 by the plaice, Pleuronectes platessa L. Jour. Exp. Mar. Biol. Ecol. 21:179-189.

Previous studies have determined that direct absorption of Zn-65 and Mn-54 plays a minor role in accumulation of these metals. Therefore tests were made to determine whether accumulation occurred via food or by absorption from water using eggs and larvae of a marine flatfish. Accumulation by embryo was negligible; larval accumulation rate of Zn-65, at 15 μg/l of Zn, represented an intake of 7.2 ng/g/day; for Mn-54, at 2 μg/l, this was 0.86 ng/g/day. Concentrations within 7 g fish (∿200 days after hatching) were 6.6 μg/g wet in muscle and 39.2 μg/g wet in bone for Zn; and 40 μg/g wet in bone for Mn. It appears that food constitutes the major pathway for accumulation. Stable element analyses of liver, muscle, and bone samples from fish of differing weights and ages show that concentrations in adult fish remain fairly constant: Zn values varied by only a factor of 3 in muscle and 2 in bone (the largest components); Mn varied by a factor of 4.4 in bone; and Fe varying by 4, 7, and 20 in bone, liver, and muscle, respectively. On this basis it has previously been estimated that biological half-times of these metals via food should be shorter than those observed after accumulation from labelled water. Experiments using radioactively-labelled Nereis diversicolor, gave effective half-times of 60 days for Zn-65 and 35 days for Mn-54, supporting this view.

1966. Pentreath, R.J. 1976. The accumulation of organic mercury from seawater by the plaice, Pleuronectes platessa L. Jour. Exp. Mar. Biol. Ecol. 24:121-132.

Accumulation of organic Hg from seawater by flatfish eggs, larvae, and adults was determined using CH_3 Hg-203 Cl. Eggs increasingly accumulated the isotope, attaining a concentration factor of 465 after 12 days. Larvae rapidly accumulated Hg also with a CF of 2000 after 8 days. In young fish, whole body CF increased with time reaching a maximum of 600 after 64 days. Highest concentration factors were in blood, spleen and kidney. Muscle had the largest accumulation of CH_3 Hg-203 Cl with 64% of total uptake. The biological half-time of CH_3 Hg-203 Cl at 275 days is greater than inorganic Hg.

1967. Pentreath, R.J. 1976. The accumulation of mercury from food by the plaice, Pleuronectes platessa L. Jour. Exp. Mar. Biol. Ecol. 25:51-65.

Flatfish were fed Hg-203Cl_2 and CH_3Hg-203Cl labelled Nereis diversicolor worms. After 5 days only 3-5% of the initial inorganic Hg dose was retained compared to 80-85% of CH_3Hg-203Cl. The methyl form of Hg was more rapidly assimilated. Three days post-exposure, 53-88% of the initial dose remained in gut lumen of fish fed inorganic Hg; less than 3% remained in gut of those fed organic Hg. In CH_3Hg-203Cl-fed plaice, Hg-203 accumulated in liver and kidney to a greater extent than the inorganic form. Mean biological half-times for elimination of Hg-203Cl_2 and CH_3Hg-203Cl were 32.9 and 163.0 days, respectively. Using a simplified model of accumulation of methylmercury from food, concentrations of Hg in fish at different ages were calculated in relation to basic physiological factors and dietary intakes. Solutions of this model showed that a considerable range of concentrations of methylmercury can be attained by individual fish depending on diet and relative weightings of parameters.

1968. Pentreath, R.J. and M.B. Lovett. 1976. Occurrence of plutonium and americium in plaice from the north-eastern Irish Sea. Nature 262:814-816.

Adult flatfish, Pleuronectes platessa, collected during 1975 from the NE Irish Sea near the Windscale nuclear reprocessing plant were analyzed radiologically for americium and plutonium. In February, highest concentrations of Pu were in kidney, followed by liver, gut, bone, gill, skin and muscle. In August, highest Pu concentrations were in gill followed by gut, kidney, liver, skin, bone and muscle. Concentrations of Am-241 were, in general, higher than those reported for Pu. In February, highest Am-241 concentrations were in liver, followed by kidney, gill, gut, bone, skin and muscle. In August, the highest Am-241 concentration was in gill, then gut, kidney, liver, bone, skin and muscle. The overall Am-241 levels were lower in August than February which might reflect a decreased discharge rate of Am-241. Data emphasizes that very low and comparatively safe levels of Pu and Am are present in edible portions of plaice, even from areas most liable to contamination.

1969. Persoone, G. and G. Uyttersprot. 1975. The influence of inorganic and organic pollutants on the rate of reproduction of a marine hypotrichous ciliate: Euplotes vannus Muller. Rev. Intern. Oceanogr. Med. 37-38:125-151.

Effects of Pb, Cu, Cd, Zn, and Hg ions, five pesticides, and a PCB on reproduction of a marine protozoa are given. There was no effect of any metal at concentrations of 0.1 mg/l. Total inhibition of reproduction occurred in 100 mg/l of Pb, Zn, or Cd; 10 mg/l of Cu; or 1 mg/l of Hg. Organochlorine pesticides and PCB were all less toxic than metals; 10 mg/l reduced reproduction rate by only 10%. When compared to metal concentrations in the environment, only sediments contained lethal levels (up to 926 mg/l Zn, 280 mg/l Pb, 221 mg/l Cu, and 1.24 mg/l Hg).

1970. Peters, A.W. and O. Burres. 1909. Studies on enzymes. II. The diastatic enzyme of Paramoecium in relation to the killing concentration of copper sulphate. Jour. Biol. Chem. 6:65-73.

Death of Paramoecia occurred within 20 seconds in the range 17.5×10^{-8} to 30×10^{-8} gm mol. per cc of copper sulphate (about 12 to 25 mg/Cu/l). A positive correlation was demonstrated between concentration of $CuSO_4 \cdot 5H_2O$ that killed instantly and that concentration which markedly inhibits the action of diastase.

1971. Peterson, R.H. 1976. Temperature selection of juvenile Atlantic salmon (Salmo salar) as influenced by various toxic substances. Jour. Fish. Res. Bd. Canada 33:1722-1730.

Preferred temperature for salmon in a horizontal temperature gradient was unaltered by metal salt levels, in mg/l, up to 0.03 for $CuSO_4$ (∿0.012 mg Cu/l), 0.39 for $ZnSO_4$ (∿0.158 mg Zn/l), or 0.002 for $CdSO_4$ (∿0.001 mg Cd/l).

1972. Phelps, D.K., G. Telek and R.L. Lapan, Jr. 1975. Assessment of heavy metal distribution within the food web. In Pearson and Frangipane (eds.). Marine Pollution and Marine Waste Disposal. Pergamon Press, New York: 341-348

Chromium levels in sediments, water and biota were determined in samples collected from Narragansett Bay, R.I. Highest levels were in sediments (range 56.7-320.0 mg/kg dry wt) followed by seston (88.8-211.0 mg/kg dry wt), phytoplankton (41.3-73.3), a polychaete annelid (23.8-38.0), quahaug clam (3.3-24.7), winter flounder (<2.2 mg Cr/kg dry wt in selected tissues), and water column (<0.005-0.032 mg/l). Authors concluded that chromium accumulation above the primary producing level of the food web is directly associated with food and feeding rather than direct uptake from water column. It was suggested that chromium levels in particle-feeding benthic organisms reflected those of polluted reservoirs such as dredge spoil disposal sites.

1973. Phillips, A.H. 1917. Analytical search for metals in Tortugas marine organisms. *In* Papers Dept. Mar. Biol. Carnegie Inst. Washington, Publ. 251, xi:91-93.

Maximum metal contents of marine organisms collected from the Dry Tortugas, in g/kg dry wt, were:

	Cu	ZnO	Fe	MnO
Molluscs				
Fasciolaria gigantea				
(liver):	3.7	0.6	1.0	0.01
Cassis sp.				
(liver):	0.10	0.10	0.5	0.008
Strombus bitubercalatus				
(soft parts):	0.03	0.07	0.56	0.055
S. gigas				
(liver):	0.04	0.38	2.0	0.22
(soft parts):	0.13	0.255	0.965	0.11
Fulgur perversus				
(soft parts):	0.035	0.39	0.57	0.008
Aplysia sp.				
(whole animal):	0.15	0.08	0.435	0.01
(liver):	0.11	0.10	0.62	0.0
Crustacea				
Palinurus sp.				
(blood):	0.7	0.0	0.86	0.07
(liver):	1.1	0.2	0.285	0.0008
Arachnoidea				
Limulus polyphemus				
(liver & gonads):	0.17	0.67	0.27	0.005
(blood):	0.85	0.07	0.29	0.042
Echinodermata				
Holothuria bermudiana				
(muscle):	0.0	0.22	0.29	trace
(intestines):	0.02	0.065	0.01	trace
Tunicata				
Ciona atra				
(whole animal):	0.015	0.030	1.18	0.01

In addition, *Fasciolara* contained 0.003 g Pb O_2/kg dry wt.

1974. Phillips, J.H. 1976. The common mussel *Mytilus edulis* as an indicator of pollution by zinc, cadmium, lead and copper. I.

effects of environmental variables on uptake of metals. Marine Biology 38:59-69.

Mussels from 3 locations in Port Phillip Bay, Australia, showed spatial and seasonal variations in metal content of whole soft parts; for all locations, content in mg/kg wet wt, ranged from 19.3 to 60.1 for Zn, 0.2 to 1.3 for Cd, and 0.61 to 0.98 for Cu. Near freshwater metal inputs, Zn, Cd and Pb levels in mussels declined with depth; when runoff was seasonally less, no variation was found. When subjected to a mixture of 400 μg Zn, 40 μg Cd, 20 μg Pb and 20 μg Cu per liter at temperatures of 10 and 18 C, a salinity decrease from $35^{o}/oo$ to $15^{o}/oo$ did not affect net uptake of Zn by mussels, but Cd uptake increased and Pb uptake decreased. At these salinities, a temperature decrease from 18 to 10 C had no effect on net Zn or Pb uptakes; uptake of Cd was unaffected by low temperature at $35^{o}/oo$, but decreased at $15^{o}/oo$. When exposed to combinations of Zn, Cd, Pb and Cu at levels, in μg/l, of 0 to 400 for Zn, 0 to 40 for Cd, 0 to 20 for Pb and 0 to 20 for Cu, the presence of other 3 metals had no effect on individual net uptake of Zn, Cd or Pb. However net uptake of Cu was extremely erratic and was affected by salinity, temperature, as well as presence of other metals.

1975. Phillips, J.H. 1976. The common mussel Mytilus edulis as an indicator of pollution by zinc, cadmium, lead and copper. II. relationship of metals in the mussel to those discharged by industry. Marine Biology 38:71-80.

Mean metal levels in mg/kg wet soft tissue of mussels from Port Phillip Bay and Western Port Bay, Victoria, Australia, ranged from 16.4 to 97.1 for Zn, 0.20 to 18.16 for Cd, n.d. to 10.02 for Pb, and n.d. to 1.45 for Cu. Author concluded that mussels act as efficient time-integrated indicators of Zn, Cd, and Pb over a wide variety of environmental conditions. Cu levels were highly variable, and it was suggested that alternative organisms be used as Cu indicators.

1976. Pic, P. and J. Maetz. 1975. Différences de potentiel trans-branchial et flux ioniques chez Mugil capito adapte a l'eau de mer. Importance de l'ion Ca^{++}. C.R. Acad. Sc. Paris 280 (Ser. D):983-986.

The trans-branchial potential results primarily from diffusion of Na^+ and K^+ along the length of their concentration gradient, and secondarily by a Cl-pump mechanism. Ca^{++} ions modulate the relative permeability of cations and Cl^-.

1977. Pic, P., N. Mayer-Gostan and J. Maetz. 1975. Branchial effects of epinephrine in the seawater-adapted mullet. II. Na^+ and Cl^- extrusion. Amer. Jour. Physiol. 228(2):441-447.

Injection of epinephrine into Mugil capito adapted to seawater is followed by a 40-60% inhibition of Na and Cl effluxes. Simultaneously Na influx is decreased by 30%, the overall result being a reduction of net Na extrusion rate by gill. Na influx change is in part explained by a 75-80% decrease of oral ingestion of seawater. This branchial adrenergic response is sensitive to α-blockade by phentolamine and tolazoline and insensitive to β-blockade by propranolol. Both α-blockers are ineffective when injected alone. Propranolol injected alone mimics epinephrine while simultaneous injection of phentolamine blocks response to propranolol. Rapid transfer experiments suggest that epinephrine inhibits the branchial Cl pump and its associated Na/K exchange mechanism. Leak pathway for these ions remains insensitive to epinephrine.

1978. Pilkey, O.H. and H.G. Goodell. 1963. Trace elements in recent mollusk shells. Limnol. Oceanogr. 8(2):137-148.

In 7 species of marine mollusks collected from much of their present range, metal contents of shells in mg/kg dry wt ranged from 0 to 438 for Mn, 3 to 1059 for Fe, 123 to 3114 for Mg, 3 to 48 for Ba and 1540 to 4097 for Sr. Differences in environmental salinity below 25^{o}/oo caused greater changes in shell composition than temperature differences. Several significant correlations between shell composition and environmental parameters were observed, but authors considered these to be too weak for paleoecological determinations.

1979. Pillai, V.K. 1956. Chemical studies on Indian seaweeds. I. Mineral constituents. Proc. Indian Acad. Sci. 44(1)Sec. B: 3-29.

Seasonal variations in 11 species of algae were determined for Na, K, Ca, Mg, Fe, Cu, Mn, B, Mo and Zn. K and Ca are absorbed more efficiently than Mg, with intensity dependent on algal type. Distinct minima in Na, K, Ca, and Mg were found between August and September, with amounts increasing from December to June. Fe content is lowest in Chlorophyceae and highest in Phaeophyceae. The maximum Fe value was 504 mg/kg dry wt in Padina australis. Cu was generally low in content with no seasonal correlations and a maximum value of 12.0 mg/kg in Acanthophora spicifera. Mn and B showed wide variations in species with minimum values in April and maximum in August; highest values were in agar-containing Rhodophycoeae. Mo has maximum values in August with a maximum value of 0.24 mg/kg dry wt in Gracilaria lichenoides. Average Zn content varies between 10 and 80 mg/kg dry wt with minimum values in Chlorophyceae and maximum values in Rhodophyceae. No seasonal variations in Zn content were found.

1980. Porter, K.R. and D.E. Hakanson. 1976. Toxicity of mine drainage to embryonic and larval boreal toads (Bufonidae: Bufo boreas). Copeia 2:327-331.

Bioassays were conducted with a Colorado mine drainage waste using zygotes and larvae of toads. Toads tolerated between 0.06% drainage (containing 0.16 mg Fe/l, 0.023 mg Zn/l, and 0.002 mg Cu/l at pH of 5.0) and 1.2% drainage (with 3 mg Fe/l, 0.5 mg Zn/l, 0.044 mg Cu/l and pH of 4.0). Incipient lethal levels, in mg/l, for individual components were: 20 to 30 for Fe, 0.1 to .05 for Zn, and 0.02 to 0.044 for Cu. Incipient lethal acidity fell within the range pH 3.1 to 4.0.

1981. Portmann, J.E. 1972. The levels of certain metals in fish from coastal waters around England and Wales. Aquaculture 1:91-96.

Mean concentrations in mg/kg wet wt of metals found in cod muscle from inshore habitats were: Cd 0.12, Cu 0.47, Cr <0.50, Hg 0.26, Pb <0.50, Zn 4.35; from the North Sea these were: Cd 0.18, Cu 0.65, Cr <0.50, Hg 0.10, Pb <0.50, Zn 5.16; and from distant waters: Cd <0.05, Cu 1.00, Cr <0.50, Hg 0.09, Pb <0.50, Zn 4.70. Mean concentrations in plaice from coastal waters were: Cd 0.07, Cu 0.85, Cr <0.50, Hg 0.25, Pb 0.54, Zn 5.36; from North Sea: Cd 0.12, Cu 0.85, Cr <0.50, Hg 0.08, Pb <0.50, Zn 5.70; and from distant waters: Cd 0.05, Cu 1.50, Cr <0.50, Hg 0.05, Pb <0.50, Zn 6.60.

1982. Portmann, J.E. and J.P. Riley. 1964. Determination of arsenic in seawater, marine plants and silicate and carbonate sediments. Anal. Chim. Acta 31:509-519.

Seawater contained 2.0 ± 0.02 μg As/l; Fucus serratus and red clay contained 1.67 ± 0.03 and 6.6 ± 0.17 mg As/kg dry wt, respectively.

1983. Potts, W.T.W. and F.B. Eddy. 1973. Gill potentials and sodium fluxes in the flounder, Platichthys flesus. Jour. Comp. Physiol. 87:29-48.

The potential between blood plasma and external medium of a euryhaline flounder is largely dependent on external concentration of sodium and acts as a diffusion potential; permeability to Ca, Mg, and SO_4 is very low. Changes of potential account for the apparent "Na exchange diffusion effect" observed in Na fluxes following changes in external medium and the slight dependence of Na efflux on external seawater K concentration. Average plasma concentrations of seawater-adapted flounder were 4.4 and 0.17 g/l for Na and K, respectively.

1984. Potts, W.T.W. and D.H. Evans. 1967. Sodium and chloride balance in the killifish *Fundulus heteroclitus*. Biol. Bull. 133:411-425.

Measurements of influx and efflux rates of Na, plus efflux rates of Cl and Br ions in this euryhaline teleost were made in seawater, 40% seawater and freshwater. The relationship between active influx, f, and external concentration, M, is given by:

$$f = f_{max} \left[\frac{M}{M+C}\right]$$

where C is concentration at which $f = \frac{1}{2} f_{max}$ and is a measure of affinity of carrier molecule to ion; with a lower C indicating a lower concentration in which an animal can survive. In *Fundulus*, $C \simeq 2$ mMNa/l. In freshwater crustacea C can be as low as 0.2 (*Astacus*) or 0.1 mM/l (*Potamon*), indicating that *Fundulus* is not as well adapted to freshwater as these crustaceans.

The most important single change during adaptation to freshwater is a reduction of permeability. Normal fish adapted to freshwater, or placed in freshwater for a short period (i.e., 15 min) maintain low permeability for many hours after return to seawater. This rapid, but not instantaneous adaptation and slow reversal suggests that permeability is controlled by a hormone released in response to freshwater, falling blood concentration, or both.

1985. Potts, W.T.W., M.A. Foster and J.W. Stather. 1970. Salt and water balance in salmon smolts. Jour. Exp. Biol. 52:553-564.

Respective sodium contents of smolting salmon adapted to freshwater and seawater were 690 and 1030 mg/kg wet wt. Total Na flux in freshwater and seawater adapted animals were 368 and 2967 mg/kg fish/day. Na flux rates, in mg/kg/hr, for smolts adapted to seawater and freshwater, respectively, were 36 and 0 for drinking influx, 87 and 16 for influx through body wall, <0.23 and 0.46 for urine loss and 124 and 15 for extra renal loss. On immediate transfer from seawater to dilute seawater or to freshwater, influxes decline rapidly; on transfer from freshwater to seawater, restoration of fluxes occurs slowly.

1986. Potts, W.T.W. and G. Parry. 1964. Sodium and chloride balance in the prawn, *Palaemonetes varians*. Jour. Exp. Biol. 41:591-601.

For *P. varians* in an isosmotic medium (∿23°/oo), exchange of Na$^+$ and Cl$^-$ took place by passive diffusion with fluxes, in g/kg animal/hr, of 1.7 and 0.7 for Na$^+$ and Cl$^-$, respectively. At 35°/oo Na$^+$ was removed extrarenally at a rate of 3.5 g/kg animal/hr; Cl$^-$ passively diffused outward at a rate of 1.8 g/kg animal/hr. Increased ion fluxes may be associated with maintenance of water balance by water-swallowing.

At 0.7°/oo, Cl$^-$ was actively absorbed at a rate of 1.0 g/kg animal/hr; which resulted in inward diffusion of Na$^+$ at a rate of 414 g/kg animal/hr. Some active Na$^+$ uptake also occurred. In seawater <0.7°/oo, equilibrium could not be maintained.

1987. Pouvreau, B. and J.-C. Amiard. 1974. Etude experimentale de l'accumulation de l'argent 110 m chez divers organismes marins. Comm. à l'Energie Atomique-France, Rept. CEA-R-4571. 19 pp.

Concentration factors (cf) were determined for Ag-110m in coastal marine organisms, some of which are marine products of commerce; results were similar to those measured *in situ* for the stable element. Tests were conducted at 15 C in static seawater containing initial concentrations of 3.33 uCi Ag 110m/1. Cf values for three species of algae ranged between 1600 and 2800 after 38 days; for bivalve mollusc flesh these were 500-32,000 (especially high in oyster after 160 days); for gastropod molluscs, cf values were 1100-3000; for 3 species of whole decapod crustaceans cf values were 75-4000; and for a teleost 40, after 98 days. Many tissues were not in equilibrium at the end of their respective exposure periods, including all species of algae, flesh of bivalve molluscs, whole fish, and fish viscera.

1988. Powers, E.B. 1920. Influence of temperature and concentration on the toxicity of salts to fishes. Ecology 1:95-112.

Goldfish were tested at various concentrations of lithium chloride (0.046 N to 0.488 N) and 5 temperatures between 4 and 34.8 C. Toxicity increased with both concentration and temperature; survival time decreased from 1411 min (0.058 N, 4 C) to 7 min (0.372 N, 34.8 C). Toxicity of ammonium chloride to goldfish, bluntnose minnow (*Pimephales notatus*) and minnows (*Notropis blennius*) increased with temperature. Temperature effect on toxicity of LiCl$_2$ and NH$_3$Cl did not follow van't Hoff's rule at extreme temperatures. Q$_{10}$ also did not meet van't Hoff's rule except at high temperatures. Relative toxic activities of LiCl$_2$ at different temperatures to goldfish follow closely the square root of relative standard metabolism of vertebrates; therefore, LiCl$_2$ may attack some intermediary substance of metabolism.

1989. Pratt, D.R., J.S. Bradshaw and B. West. 1972. Arsenic and selenium analyses in fish. Utah Acad. Arts Sciences Proc. Part 1, 49:23-26.

A procedure for analysis of arsenic and selenium in freshwater fishes is described. Values obtained for As (in ug/kg wet wt) were: bass 35-172, carp 55-210, catfish 79-298, sucker 62-253, and trout 69-149. For selenium these were: bass 375-1265, carp 328-1896, catfish 387-2659, sucker 444-1522, and trout 397-792.

1990. Preston, A., J.W.R. Dutton and B.R. Harvey. 1968. Detection, estimation, and radiological significance of silver-110m in oysters in the Irish Sea and the Blackwater Estuary. Nature 218:689-690.

Oysters *Ostrea edulis* from Blackwater Estuary adjacent to a nuclear power station contained in pCi/g wet wt: 0.79 Fe-55; 0.35 Co-60; 43.1 Zn-65; 0.38 Ag-110m; and 0.17 Cs-137. Irish Sea oysters had concentrations, in pCi/g wet wt, of: ∿5 Ce-144; 15 Ru-106; ∿2 Zr-95/Nb-95; 2.3 Ag-110m; 2.4 Zn-65; and 3.5 K-40. Silver-110m is 3.3X more radiotoxic than Zn-65, but this difference is almost offset by the greater concentration factor for zinc in oyster flesh. Although Zn-65 in effluent is almost 50X greater than Ag-110m (4.44 *vs* 0.070), the two nuclides are of almost equal importance per curie released.

1991. Preston, A., D.F. Jeffries, J.W.R. Dutton, B.R. Harvey and A.K. Steele. 1972. British isles coastal waters: the concentrations of selected heavy metals in sea water, suspended matter and biological indicators—a pilot survey. Environ. Pollut. 3:69-82.

Highest concentrations of metals in seawater from the eastern Irish Sea, in ug/l, were: Zn 7.1, Fe 11.9, Mn 6.1, Cu 1.7, Ni 2.6, Pb 1.6, Ag 0.08, and Cd 0.46. Metal concentrations were also determined for bladder wrack *Fucus vesiculosus*, laverweed *Porphyra umbilicalis*, and limpets (soft parts) *Patella vulgata*. The highest concentrations found, in order respectively, were in mg/kg dry wt: Zn 171, 66, 158; Fe 249, 387, 2450; Mn 99, 29, 42; Cu 10.1, 11.5, 14.4; Ni 6.7, 2.2, 7.3; Pb 4.0, 3.1, 7.9; Ag 0.35, 0.13, 2.1; and Cd 1.4, 0.35, 13.1. Little change was found in metals levels of *Fucus* during 10 years prior to 1970 samples. Concentration factors are also given, showing a high reconcentration of Fe, Ag and Cd in flesh of *Patella*. *Fucus* appears to be a good indicator species for Zn, Fe, Mn, and Ag. In general, proportions of metals associated with suspended matter remain fairly constant with respect to variations of total concentrations in either time or space.

1992. Prytherch, H.F. 1931. The role of copper in the setting and metamorphosis of the oyster. Science 73(1894):429-431.

Laboratory studies demonstrated that concentrations of copper in the range 0.02-0.04 mg/l initiated almost immediately a positive setting reaction of oyster larvae; no such effect was observed with compounds of tin, iron, zinc, lead, aluminum, manganese, and silver. In river water copper was present in amounts varying from 0.2-1.25 mg/l and is apparently the specific element essential for oyster attachment, metamorphosis, and survival. Highest set of spat in Milford Harbor, Connecticut, occurred when copper content of the water ranged from 0.15 to 0.50 mg/l; setting ceased when copper content dropped below 0.01 mg/l. Author states that because copper plays an important role in oyster respiratory processes, its presence would naturally enhance release of cells necessary for setting and metamorphosis. Author cautions that at slightly higher concentrations (presumably >1.25 mg/l) copper quickly produces cytolysis and death of oyster larvae.

1993. Prytherch, H.F. 1934. The role of copper in the setting, metamorphosis, and distribution of the American oyster, Ostrea virginica. Ecological Monographs 4(1):47-107.

The stimulus for setting of oyster larvae has been traced to surface and underground waters flowing into inshore coastal areas, and specifically to presence of minute amounts of copper in these waters. The duration of the setting process varied in waters of different salinities and reached its optimum or shortest interval in salt concentrations of 16-18.6^{o}/oo when setting is completed in from 12-19 minutes. Under natural conditions the setting of oyster larvae was most pronounced at the stage of tide when copper content of water was highest, and within a range of from 0.05 to 0.6 mg of copper per liter. Within this range the intensity of setting or number of individuals corresponding to copper stimulation was directly proportional to the amount of copper present. The oyster larva receives the stimulus for setting through ingestion of copper in the form of a colloidal precipitate and reacts to its presence after an average latent period of 4 minutes and 20 seconds.

Copper is highly toxic to the larva when the concentration is in excess of that found in natural waters, and gradually produces cytolysis of the tissues and death of the organism. The metamorphosis of the attached larva and its development are dependent upon the ingestion of additional amounts of copper. The horizontal and vertical distribution of oysters in different coastal regions can be correlated with the copper content, salinity of the water, and the variations in these factors under different hydrographical and tidal conditions. The location of the most prolific areas for setting and seed oyster production is determined largely by the degree of interaction between fresh water and sea water and particularly by the amount of copper supplied by the former.

1994. Pugh, P.R. 1975. Variations in the biochemical composition of the diatoms *Coscinodiscus eccentricus* with culture age and salinity. *Marine Biology 33*:195-205.

Marine diatoms were grown at 20, 25, 30 and 35^{o}/oo. Changes in carbohydrate, protein, silicon and pigment concentrations of cells throughout the growth cycle were monitored. Carbohydrates and pigments showed no salinity dependence, whereas protein and silicon concentration did. At the start, dry wt % silica contents were 30, 32, 30, and 31% in 20, 25, 30, and 35^{o}/oo S, respectively; whereas at the end these values were 16, 15, 13, and 11%, respectively. Changes in frustular thickness were also calculated.

1995. Raeder, M.G. and E. Snekvik. 1949. Mercury determinations in fish and other aquatic organisms. Kongl. Norske Vidensk. Selskab. 21(25):102-104.

Mercury concentrations in fish fillets were 136 to 166 μg/kg in *Anarrhichas lupus*, and 75 μg/kg in *Salmo alpinus*.

1996. Raeder, M.G. and E. Snekvik. 1949. Mercury contents of fish and other aquatic organisms. Kongl. Norske Vidensk. Selskab. 21(25):105-109.

Mercury, in ug Hg/kg, of freshwater organisms was: 142 for *Gasterosteus pungitis*, a stickleback; 167 for *Anguilla vulgaris*, an eel; 94-136 for *Salmo trutta*, a trout; 100-138 for *Salmo alpinus*; 288 for *Limnea*, a snail; 89 for *Perca fluviatilis*, a perch; 77 for *Lota lota*, the turbot (fish); and 76 for *Coregonus lavaretus*, a whitefish. Marine organisms studied, and their concentrations (in ug Hg/kg) were: *Gadus morrhua*, codfish, 44 in liver to 180 in soft roe; *Cancer pagurus*, crab, 60 in shells and 62 in pulpy parts; and *Pandalus borealis*, shrimp, 51 in pulpy parts to 114 in shells and head. It was concluded that interspecies differences were due to variations in food and feeding habitat, with primary Hg intake via digestive tract rather than gills.

1997. Ramamoorthy, S. and D.J. Kusher. 1975. Binding of mercuric and other heavy metal ions by microbial growth media. Microbial Ecol. 2:162-176.

Addition of 20 mg/1 of Hg^{2+}, Pb^{2+}, or Cu^{2+} to widely used bacterial growth media resulted in binding of all but 80 ug/1 of each metal. Cd^{2+} did not bind as completely as Hg^{2+}, Pb^{2+}, or Cu^{2+}. Authors state that ions either enter bacterial cells as organic complexes, or bacteria successfully compete with growth media for bound ions.

1998. Rana, B.C. and H.D. Kumar. 1974. The toxicity of zinc to *Chlorella vulgaris* and *Plectonema boryanum* and its protection by phosphate. Phykos 13:60-66.

Relatively high concentrations of phosphate, but not nitrate, improves growth of 2 species of freshwater algae and also protects against increased zinc toxicity to a certain limit. In low concentrations, nitrate also stimulates growth but fails to protect *C. vulgaris* against toxicity caused by high zinc content. Phosphate protection against zinc signifies a possible ecological role of phosphate in eutrophic habitats in reducing toxicity of metal ions, thereby encouraging growth of sewage organisms. Authors conclude that phosphate ions may complex with zinc to produce a non-ionic product of low biological activity.

1999. Rana, B.C. and H.D. Kumar. 1974. Effects of toxic waste and waste water components on algae. Phykos 13:67-83.

Several species of freshwater algae were exposed to effluents of a zinc smelter. *Anacystis nidulans*, *Oscillatoria* sp. and *Nodularia spumigena* were most sensitive and failed to grow at any pH tested. *Chlorella vulgaris* survived in effluent at pH 5.0 with improved growth as pH rose to 8.0; *Scenedesmus* sp. was similar to *Chlorella* while *Plectonema boryanum* grew only in effluent at pH 8.0. Respective 10-day LC-50 values in mg/1, for Zn^{2+} and $CuSO_4$, were 1.0 and 0.4 for *Anacystis nidulans*, 0.5 and 0.5 for *Oscillatoria* sp., 0.4 and 0.4 for *Anthrospira jenneri*, 10.0 and 4.0 for *Plectonema boryanum*, 0.7 and 0.5 for *Nodularia spumigena*, 5.0 and 2.5 for *Chlorella vulgaris* and 5.0 and 4.0 for *Scenedesmus* sp.

2000. Rancitelli, L.A., W.A. Haller, and J.A. Cooper. 1968. Trace element variations in silver salmon and king salmon muscle tissue. Rapport Americain BNWL-715 Part 2:42-47.

For silver salmon, average metal contents from white, cheek, and red muscle tissue, in mg/kg freeze dried tissue, ranged from 920 to 3380 for Na, 9600 to 16,800 for K, 3.6 to 5.6 for Rb, 0.056 to 0.105 for Cs, 7.6 to 40.0 for Fe, 12 to 50 for Zn, 0.73 to 0.98 for Se, 0.2 to

0.6 for Hg, 0.006 to 0.014 for Co, 0.00003 to 0.00009 for Sc, 0.0002 to 0.0004 for Sb, and <0.001 for Ag. Average liver values, in mg/kg freeze dried wt, were 3000 for Na, 18,000 for K, 7.2 for Rb, 0.047 for Cs, 270 for Fe, 95 for Zn, 3.8 for Se, 0.3 for Hg, 0.17 for Co, 0.0002 for Sc, 0.17 for Ag, and 0.0008 for Sb. A correlation between K, Rb, and Cs exists, as well as a correlation between Na and Zn. The ratio Rb:K in muscle tissue is similar to that of seawater, while Cs:K shows a 10-fold increase over that of seawater. Average metal concentrations, in mg/kg freeze dried wt, of Alaskan king salmon red muscle were 1600 for Na, 13,000 for K, 3 for Rb, 0.12 for Cs, 15 for Fe, 22 for Zn, 1.6 for Se, 0.8 for Hg, 11 for Co, 0.0002 for Sc, <0.001 for Ag, and 0.0009 for Sb.

2001. Rancitelli, L.A., C.E. Jenkins and W.A. Haller. 1967. Trace element content and the specific activity of several radionuclides in silver salmon liver. Rapport Americain, BNWL-715, Part 2:47-52.

Concentrations of metals in mature salmon livers from Washington State, in mg/kg freeze-dried tissue, were: 3000 for Na, 18,000 for K, 6.6 for Rb, 0.047 for Cs, 95 for Zn, 270 for Fe, 0.17 for Co, <0.02 for Cr, 0.17 for Ag, 0.001 for Sb, <0.0002 for Sc, 3.8 for Se, and 0.3 for Hg. Specific radioactivities of K-40 and Cs-137 in salmon liver are similar to those in seawater, but Co-60 and Zn-65 are higher; these differences may be due to contact with the Columbia River where high concentrations of Zn-65 and Co-60 are present.

2002. Rathsack, R. and K. Lohs. 1969. Zur aufnahme von kupferverbindungen durch Chlorella pyrenoidosa. Studia Biophys. Berlin 13(4):209-215. (In German, English summary)

In range of 0.64 to 640.0 ug Cu/l, the Cu complex of triethanolamine was more toxic and taken up more rapidly by Chlorella than $CuSO_4$. Permeation rate of Cu complex to algae appeared higher despite its greater stability.

2003. Ratkowsky, D.A., T.G. Dix, and K.C. Wilson. 1975. Mercury in fish in the Derwent Estuary, Tasmania and its relation to the position of the fish in the food chain. Australian Jour. Mar. Freshwater Res. 26:223-231.

Total mercury concentrations are reported for 258 individuals representing 16 species of finfish from the Derwent Estuary, Tasmania. Hg concentrations in muscle varied between 0 and 2.0 mg/kg in a school shark Galeorhinus australis. Ralphs Bay contained a higher percentage of fish with Hg concentrations in excess of Tasmanian Food Regulation limit of 0.5 mg/kg than any other area of the Estuary. Approximately 51% of individual piscivorous fish had Hg concentrations >0.5 mg/kg; by contrast, 24% of invertebrate predators and only 7% of individual herbivores had Hg concentrations >0.5 mg/kg.

2004. Read, L.J. 1971. Chemical constituents of body fluids and urine of the holocephalan Hydrolagus collei. Comp. Biochem. Physiol. 39A:185-192.

Levels of Na, K, Mg, Ca and other substances were determined in serum, cranial fluid and urine of ratfish. Levels of urea and trimethylamine oxide are lower, and Na and Cl higher in ratfish body fluids than elasmobranchs. However, similarities in electrolyte distribution with elasmobranchs suggest a similar pattern of renal and possibly extrarenal function.

2005. Reed, J.R. 1975. Uptake and elimination of radiotungsten in black bullheads. In Howell, F.G., J.B. Gentry and M.H. Smith (eds.). Mineral Cycling in Southeastern Ecosystems. U.S. Energy Res. Dev. Admin.: 435-444. Available as CONF-740513 from NTIS, U.S. Dept. Comm. Springfield, VA 22161.

Catfish Ictalurus melas, took up radiotungsten from food and water with a plateau in whole-body activity after immersion for 4 days at 14 C. Fish accumulating W-187 from water had a single exponential component of elimination with a biological half-life of 2.75 days. Fish dosed in a single feeding lost activity at two rates; one component had a half-life of 14 hr and the other 6 days. After 8 days, flesh, gills, bone and gut together contained 78.6% of total activity. Bone had longest half-life (8.0 days) of examined tissues and contained 69.8% of whole-body activity after 16 days of elimination.

2006. Reese, M.J. 1937. The microflora of the non-calcareous streams Rheidol and Melindwr with special reference to water pollution from lead mines in Cardiganshire. Jour. Ecol. 25:385-407.

Collections of microflora in the Rheidol and Melindwr Rivers above and below sources of pollution from lead mines, show that micro- and macroflora abundance was greater in unpolluted (upstream) sections than polluted downstream areas. This difference in growth was present at all seasons and with all water level variations. Author suggests that this may not be due to lead itself, but to presence of silt derived from mines and deposited on stream bed.

2007. Regier, L.W., P.M. Jangaard, H.E. Power, B.E. March and J. Biely. 1974. Composition and nutritive characteristics of Atlantic Canadian white fish meals. Jour. Fish. Res. Bd. Canada 31: 201-204.

Whitefish meals from plants in eastern Canada, were analyzed for proximate composition, minerals, vitamins, amino acids, available lysine, and pepsin digestibility. The composite samples were similar in chemical composition with respect to both macro- and micronutrients. In vitro pepsin digestibility was 95-96% and chemically estimated available lysine 6.5-6.9 g/16 g N, or 87-96% of the total lysine present. Mineral analyses yielded average values of (%): 5.4 Ca, 0.18 Mg, 1.0 K, 1.1 Na, and (mg/kg): 123.0 Al, 2.5 Ba, 13.0 B, 9.6 Cr, 6.4 Cu, 85.0 Fe, 9.8 Mn, 0.24 Hg, 2.0 Se, >200.0 Sr, and 64.0 Zn.

2008. Rehwoldt, R. and D. Karimian-Teherani. 1976. Uptake and effect of cadmium on zebrafish. Bull. Environ. Contamin. Toxicol. 15:442-446.

Uptake of cadmium over a 6 month period by the freshwater Brachydanio rerio, fed a daily diet containing 10 mg Cd/kg as Cd $(CH_3COO)_2$, was recorded and compared to controls. Cadmium uptake increased rapidly, then slowed with a plateau after approx. 3 months. Maximum Cd concentration attained in females was 12.7 mg/kg dry wt; for males this was 5.1 mg/kg dry wt. Coloration and markings of Cd-fed fish became less defined. After 30 days, the monthly total of eggs declined. Residue analysis of offspring yielded no detectable amounts of Cd, indicating that Cd is retained by parents and not transferred to the F_1.

2009. Rehwoldt, R., D. Karimian-Teherani and H. Altmann. 1975. Measurement and distribution of various heavy metals in the Danube River and Danube Canal aquatic communities in the vicinity of Vienna, Austria. Science Total Envir. 3:341-348.

Mud, water, algae and fish collected over a ten-month period were analyzed by neutron activation for Cr, Co, Sb, Zn, Sc, and Fe. Metal content of algal samples measured in mg/kg dry wt were: 8 to 12 for Co; 12 to 20 for Cr; 6006 to 7124 for Fe; 6 to 8 for Zn; 2 to 6 for Sb; and 2 to 9 for Sc. Metal content of whole homogenated carp or whitefish, in mg/kg dry wt, collected from the river were: Co, 0.31; Cr, 0.50; Fe, 14; Zn, 7.0; and Sc, 0.029. Values for those fish found in the Canal were: Co, 0.24; Cr, 0.48; Fe, 16; Zn, 7.6; and Sc, 0.030; Sb was not detectable in all fish samples.

2010. Rehwoldt, R., D. Karimian-Teherani and H. Altmann. 1976. Distribution of selected metals in tissue samples of carp, Cyprinus carpio. Bull. Environ. Contamin. Toxicol. 15:374-377.

Gill content of Co, Cr, Fe, Zn, La and Sc, in carp C. carpio, resemble that of suspended solids. This may be due to filtering function of gills with resultant high concentrations of metals adhering to particles imbedded on gill surfaces and not in tissue itself. Metals tested also appear to concentrate in viscera. Concentrations in liver, in mg/kg dry wt, were 0.07 for Co, 0.21 for Cr, 19.3 for Fe, 7.0 for Zn, 0.44 for La, and 0.20 for Sc. In kidney, metal content was 0.03 for Co, 0.08 for Cr, 2.4 for Fe, 8.4 for Zn, 0.03 for La, 0.05 for Sc. In contrast to the other metals, La and Sc tended to concentrate in bone, at 1.1 and 0.6 mg/kg dry wt, respectively. Co also accumulated in bone tissue at 0.06 mg/kg dry wt.

2011. Reichle, D.E., P.B. Dunaway and D.J. Nelson. 1970. Turnover and concentration of radionuclides in food chains. Nuclear Safety 11:43-55.

Accumulation and retention of radionuclides (Ca, Sr, K, Cs, Na, Co, Zn, Mn, Ru, Fe, Ra, Zn, Sc, As, Cu, Cr, and Ce) by terrestrial and aquatic organisms, including algae, higher plants, crustaceans, insects, molluscs, amphibians, fish and reptiles are reviewed. Data are presented for use in environmental models and correlation with species characteristics, such as body size, that allow estimation of absolute values for many different animal groups based on existing knowledge.

2012. Reinert, R.E., L.J. Stone and W.A. Willford. 1974. Effect of temperature on accumulation of methylmercuric chloride and p,p'DDT by rainbow trout (Salmo gairdneri). Jour. Fish. Res. Bd. Canada 31:1649-1652.

Yearling trout exposed to methylmercuric chloride at concentrations of 0.234-0.263 ug/l for 12 weeks at 5, 10, and 15 C accumulated 1.19, 1.71, and 1.96 mg/kg, respectively. Trout exposed to p,p'DDT at concentrations of 0.133-0.776 ug/l accumulated 3.76 (5 C), 5.93 (10 C), and 6.82 mg/kg (15 C). Concentrations of mercury accumulated were significantly different (P <0.01) at each of the three temperatures; concentrations of DDT were significantly different at 5 vs 10 C and 5 vs 15 C.

2013. Reinhart, K. and T.D. Myers. 1975. Eye and tentacle abnormalities in embryos of the Atlantic oyster drill, *Urosalpinx cinera*. Chesapeake Sci. 16(4):286-288.

Multiple development of eyes and cephalic tentacles occurred in 2.7% of *U. cinera* embryos exposed to 0.01 mg Hg/1 as $HgCl_2$ for 3 to 24 days. Abnormalities occurred in 0.4% of control animals. Abnormal animals had 1 to 3 tentacles and 1 to 6 eyes.

2014. Reish, D.J., J.M. Martin, F.M. Piltz and J.Q. Word. 1976. The effect of heavy metals on laboratory populations of two polychaetes with comparisons to the water quality conditions and standards in southern California marine waters. Water Research 10:299-302.

Toxicities of salts of Cd, Cr^{+6}, Cu, Pb, Hg, and Zn were determined for two species of polychaete annelids in seawater. Respective LC-50's (96 h) and LC-50's (28 d), in mg/1, for *Neanthes arenaceodentata* adults (juveniles) were: 12.0 (12.5) and 3.0 (3.0) for Cd; >1.0 (>1.0) and 0.55 (0.7) for Cr^{+6}; 0.3 (0.3) and 0.25 (0.14) for Cu; >10.0 (>7.5) and 3.2 (2.5) for Pb; 0.022 (0.1) and 0.017 (0.09) for Hg; and 1.8 (0.9) and 1.4 (0.9) for Zn. Respective LC-50's (96 h) and LC-50's (28 d), in mg/1, for *Capitella capitata* adults (trocophores) were: 7.5 (0.22) and 0.7 for Cd; 5.0 (8.0) and 0.28 for Cr^{+6}; 0.2 (0.18) and 0.2 for Cu; 6.8 (1.2) and 1.0 for Pb; <0.1 (0.014) and 0.1 for Hg; and 3.5 (1.7) and 1.25 for Zn. Results were compared to water quality standards for discharges in the State of California. Amounts of Cu and Zn present in two Los Angeles County sewage outfalls exceeded the LC-50 (28 d) values of both species of polychaetes.

2015. Renfro, J.L., B. Schmidt-Neilson, D. Miller, D. Benos and J. Allen. 1974. Methyl mercury and inorganic mercury: uptake, distribution, and effect on osmoregulatory mechanisms in fishes. *In* Vernberg, F.J. and W.B. Vernberg (eds.). Pollution and Physiology of Marine Organisms, Academic Press, N.Y.: 101-122.

Sodium-depleted killifish *Fundulus heteroclitus*, could not take up Na in mercury-free water after exposure to 0.125 mg $HgCl_2$/1 for 24 hrs. Fish exposed to 0.125 mg methyl-Hg/Cl for 24 hrs began to take up Na after 30 min, eventually reaching levels obtained in control groups. Neither Hg treatment increased gross Na efflux. Uptake of Hg-$203Cl_2$ occurs rapidly in killifish gills, with gradual increase in liver and kidney, reaching 90% and 70% of gill concentration, respectively, after 72 hr. Gills also take up CH_3Hg-203Cl rapidly, but liver concentration reaches 189% that of gills in 48 hrs, and kidney concentration reaches 293% of gill content in 72 hrs. C-Hg bond appears to break soon after methyl-HgCl uptake.

Urinary bladders from winter flounder Pseudopleuronectes americanus, showed decreased net Na transport without recovery when exposed to 108 mg $HgCl_2$/1, but an immediate reduction of Na reabsorption followed by recovered ability after 30-60 min when exposed to 100 mg CH_3HgCl/1. Na-K-ATPase activity was totally inhibited by 10.8 mg $HgCl_2$/1 and 80% inhibited by 12.5 mg methyl-HgCl/1.

Eels Anguilla rostrata, exhibited mean values of 0.618 and 1.28 mg Hg/kg muscle when kept for 1 month in salt and freshwater, respectively; intracellular K decreased with Hg accumulation in muscle.

2016. Renfro, W.C., S.W. Fowler, M. Heyraud and J. LaRosa. 1975. Relative importance of food and water in long-term zinc-65 accumulation by marine biota. Jour. Fish. Res. Bd. Canada 32:1339-1345.

Shrimp, crabs, and fish were maintained for 3 months in a Zn-65-labelled simulated ecosystem in which individuals were allowed to accumulate radiotracer either directly from water or from a combined food and water pathway. Shrimp and crabs receiving Zn-65 from the food-water milieu did not attain significantly higher Zn-65 body burdens than those that accumulated the isotope from water only. For fish, food pathway accounted for only 2.5 times more Zn-65 than that accumulated directly from water. Specific activity measurements of both organisms and water as well as comparisons of radioactive concentration factors with those based on stable element measurements indicated that Zn-65 in organisms had not reached equilibrium with isotope in water, even though net Zn-65 accumulation in shrimp and crabs had ceased by the end of the experiment. It was concluded that there are zinc pools within adult organisms that exchange only slowly, if at all, with zinc atoms available in the organisms' food or surrounding water. Hence, aquatic organisms such as those used in this study can most likely achieve true isotopic equilibrium only after living significant portions of their actively growing life stages in a radioactive environment.

2017. Renzoni, A. and E. Bacci. 1976. Bodily distribution, accumulation and excretion of mercury in a freshwater mussel. Bull. Environ. Contamin. Toxicol. 15:366-373.

Total mercury values of Unio elongatulus from the Paglia River in central Italy, an area of mercury mining and processing, never exceeded 0.2 mg/kg with a mean of 0.12 mg/kg. In whole soft parts of small individuals, Hg concentration ranges from 0.192 to 0.385 mg/kg (mean 0.280 mg/kg). Mercury distribution was analyzed in large mussels: digestive gland showed highest level of 1.403 mg/kg; gills and gonads were next with 1.259 and 1.232 mg/kg, respectively. Mantle, foot and adductor muscle had lower mean Hg concentrations of 0.866, 0.855 and 0.818 mg/kg, respectively. Mercury biological half-life ranged from 15 to 35 days in digestive gland, gills and gonads to about 60 days for foot abductor muscle and mantle.

2018. Rice, T.R. 1956. The accumulation and exchange of strontium by marine planktonic algae. Limnol. Oceanogr. 1:123-138.

Of 12 species of planktonic algae grown in medium containing Sr-89 and Sr-90, only *Carteria* and *Thoracomonas* accumulated Sr-90. Other species took up Y-90, the radioactive daughter of Sr-90. Removal of Y-90 from medium by *Carteria* was due to surface adsorption, whereas Sr-90 was taken into cells. Sr uptake was correlated with division rate and medium concentration of Sr, but was not influenced by high Cu levels. *Carteria* could not divide in absence of Ca; Sr could not be substituted for Ca in *Carteria* metabolism. *Nitzschia closterium* concentrated Sr 17X over seawater. Concentration factor for Sr in *Carteria*, though greater than that for *Nitzschia*, was variable, and influenced by rate of cell division, age of culture, and initial pH of medium. Radioactive Sr was not lost from *Carteria* unless medium contained a chelating compound. Some loss of radioactive Sr occurred when cells were filter washed with several different types of solutions.

2019. Rice, T.R. 1965. The role of plants and animals in the cycling of radionuclides in the marine environment. Health Physics 11:953-964.

The capacity of organisms (algae, fish, crustaceans, molluscs) to concentrate and cycle in the marine environment radionuclides, such as Cs, Sr, Sb, Te, Mo, Ru, Ce, Zr, Y, Nb, P, Zn, Mn, K, and Fe is reviewed. The level to which an isotope is concentrated by an organism varies with species, season, geographical location and other factors imperfectly understood. Biota plays an important role in radionuclide cycling through metabolism when living, and through decomposition after death. The availability of radionuclides to marine organisms is dependent on its physical state, dissolved or particulate. These materials can: remain in solution or suspension; precipitate and settle on the bottom; or be accumulated by plants and animals. Each radionuclide takes a characteristic route and has its own rate of movement from component to component, water sediment or biota, before attaining equilibrium. For an organism to be of significance in marine cycling of radionuclides, it must accumulate and retain it, and constitute a portion of a food chain. Organism obtains radionuclides by absorption, adsorption and ingestion and loses them via excretion and decomposition. Sediments accumulate radionuclides through physical processes of exchange and adsorption, with water acting as transport medium between biota and sediments.

2020. Rice, T.R., J.P. Baptist, F.A. Cross and T.W. Duke. 1972. Potential hazards from radioactive pollution of the estuary. In Ruivo, M. (ed.). Marine Pollution and Sea Life. Fishing Trading News (Books) Ltd., London: 272-276.

This report summarizes results of many studies on effects of radioactive wastes upon marine estuary systems. One study followed movement of Zn-65 added to a closed, and to an open system. After 100 days, >95% of Zn-65 and stable Zn was in sediment of each pond. Analysis of specific activity in components of ecosystem indicated that exchange of Zn between sediment and water dominated cycling and controlled distribution of Zn-65.

Uptake of Co-60, -57, -58, Zn-65, Sr-85, Cs-137 and Ce-144 was determined in the copepod Tigriopus californicus: concentration factors varied from <2 for Sr-85 to >500 for Ce-144 after 48 hrs. In another experiment, food was a more important source of Zn-65 than water for brine shrimp Artemia salina. Carnivorous fish excreted particulate radionuclides: 99% of Ce-144 pipetted directly into stomachs of croakers Micropogon undulatus, was excreted in 24 hrs. An experiment was conducted to measure uptake of Zn-65 from seawater by phytoplankton (Chlamydomonas), zooplankton (Artemia salina), postlarval croakers (Micropogon undulatus) and killifish (Fundulus heteroclitus). Zinc-65 was readily transferred through the food chain to the fourth trophic level. Postlarval fish took up Zn-65 rapidly during the first few days, but uptake rate soon decreased and Zn-65 content remained more or less constant. Radioactivity in killifish continued to increase throughout. With daily feeding, 3.8% of Zn-65 concentration in phytoplankton reached fourth trophic level; with alternate day feeding, this was 1.1%. The fourth trophic level Zn-65 concentrations were 1.4 and 9.7%, respectively, of third trophic level concentrations.

In a final study, effects of low-level chronic irradiation on division rate of phytoplankton was studied. Nitzschia closterium cells were grown at an initial culture of 2 million cells and 14.3 uCi of Cs-137/l of medium. After 26 weeks the Cs-137 was increased to 143.0 uCi/l; during a 56 week period, cells grown in Cs-137 medium divided 426X, and controls 427X.

2021. Roberts, D. and C. Maguire. 1976. Interactions of lead with sediment and meiofauna. Marine Poll. Bull. 7:211-213.

Concentrations of lead up to 10 ug/l are readily sorbed onto sediments by physical rather than biotic processes. Harpacticoid copepods and Turbellaria appear to be the most sensitive faunal groups in surface sand meiofauna when subjected to lead contamination; other taxa including flatworms, nematodes and ostracods showed no effects at concentrations up to 1000 ug/l Pb. In sub-surface sand (7-15 cm depth), nematodes were the most sensitive group.

2022. Roberts, T.M., P.B. Heppleston and R.D. Roberts. 1976. Distribution of heavy metals in tissues of the common seal. Marine Poll. Bull. 7:194-196.

Lead, cadmium and mercury content of soft tissues and bone were determined for the common seal *Phoca vitulina*, taken from coasts of East Anglia and West of Scotland. Lead levels were low in all tissues, with greatest mean accumulations of 4.0 and 3.5 mg/kg wet wt in claw and rib, respectively. Cadmium levels were also low but tended to accumulate with age in liver and kidney of West Scotland seals reaching levels of 1.1 and 1.9 mg/kg wet wt, respectively. Movement of lead and cadmium across the placenta was not significant. Total Hg levels up to 110 mg/kg wet wt were found in liver tissue of seals from both areas but much lower concentrations occurred in all other tissues analyzed. Comparison with results of other workers suggests that rate of Hg accumulation in liver of seals increases in the order: Canadian Arctic and Atlantic coast < West Scotland < East Anglia < Netherlands coast. Accumulation of mercury in kidney and spleen of older seals lends support to hypothesis that protective demethylation and retention process in liver may begin to leak mercury to other tissues at the high concentrations which have been recorded in the liver of older seals, and at high dose rates which have been used in toxicological experiments.

2023. Robertson, D.E. 1967. Trace elements in marine organisms. Rapport Americain BNWL 481-2:56-59.

Using neutron activation analysis, the following metal concentrations, in mg/kg ash, were obtained:

	Ag	Sb	Co	Sc	Zn
Squid	8.1	0.46	0.93	0.010	710
Lantern fish	4.4	0.83	0.22	0.009	210
Rat-tail fish	<1	2.5	0.56	0.16	270
Saury	<1	1.6	0.38	0.006	410
Euphausiid	<1	1.9	0.63	0.016	430
Sabel eel	<1	<0.2	0.14	0.045	180
Seawater	4×10^{-5}	3×10^{-3}	5×10^{-4}	1×10^{-6}	1×10^{-2}

Enrichment factors as high as 1 to 2 x 10^4 for Ag were observed in squid and lantern fish, while rat-tail fish concentrated scandium by a factor of 1.6 x 10^4. Co and Zn were concentrated to a somewhat lesser extent, while Sb was not significantly accumulated.

2024. Robertson, D.E., L.A. Rancitelli, J.C. Langford and R.W. Perkins. 1972. Battelle-Northwest contribution to the IDOE base-line study. Battelle Pacific Northwest Laboratories, Richland, Washington, 99352. 46 pp.

Baseline concentrations of Ag, As, Ca, Cd, Co, Cr, Cs, Cu, Eu, Fe, Hf, Hg, K, Na, Pb, Rb, Sb, Sc, Se, Sr, Ta, Tb, Th, and Zn were measured in sediments and marine organisms, including penguins, seals, crustaceans, fishes, molluscs, algae and echinoderms. High arsenic levels were found in long-fin cod and rattail muscle tissues (540 and 190 mg/kg dry wt, respectively), taken off the Oregon Coast. Arsenic levels in all organisms were significantly higher than values reported previously. Mercury concentrations in Pacific coastal organisms were below the tolerance level in edible seafood of 0.5 mg/kg wet wt tissue, except in muscle, liver and kidney tissues of the same rattail fish containing high As levels. Mercury concentrations in salmon were all relatively low (0.1 to 0.4 mg/kg dry wt). Lead concentrations in Pacific coastal organisms never exceeded the detection limit of 2 to 3 mg/kg dry wt tissue. Cadmium levels in muscle tissue of various organisms never exceeded 1 mg/kg (dry wt), but a very high concentration of 38 mg/kg Cd (dry wt) was found in rattail kidney tissue. Several whole organisms contained Cd levels ranging between 1 to 5 mg/kg (dry wt), which indicates that Cd is concentrated in internal organs of some marine animals. Copper concentrations show variation within species, while Zn concentrations are constant, suggesting definite physiological requirements. Significant variations in concentration of other elements, including Se and Co were also evident.

Concentrations of Hg, Cd, Se, Sb, and Fe were observed in liver tissue of seal and penguin specimens obtained from the Antarctic. Mercury concentrations as high as 70 to 120 mg/kg (dry wt) were observed in seal liver tissue, and a Cd concentration of about 90 mg/kg was found in liver of an Adelie penguin. High levels of these trace metals are possibly accumulated by natural processes, since man's additions of trace metal pollution in this region is almost non-existent.

2025. Robertson, J.D. 1949. Ionic regulation in some marine invertebrates. Jour. Exp. Biol. 26:182-200.

Body fluids of representatives from five invertebrate phyla were analyzed for ionic composition before and after dialysis in collodion sacs against samples of ambient seawater. Mesogloeal tissue fluid of coelenterate *Aurelia aurelia* showed the following composition, expressed as % of concentration in dialysed fluid: 99 for Na, 106 for K, 96 for Ca, 97 for Mg, 104 for Cl, and 47 for SO_4. Regulation seems to be brought about by elimination of SO_4 and accumulation of K by epithelia bounding the mesogloea, with resultant alteration of remaining ions in conformity with osmotic equilibrium between *Aurelia* and seawater. In echinoderms only K was regulated, values in perivisceral fluid did not exceed 111%, with higher values in ambulacral fluid. Polychaetes regulated K (up to 126%) and sometimes reduced SO_4 (92%). Regulation extended to all ions in decapod crustacea. In 6 species the range was 104 to 113% for Na, 77 to 128% for K, 108 to 131% for Ca, 14 to 97% for Mg, 98 to 104% for Cl and 23 to 99% for SO_4. In the series *Lithodes*, *Cancer*, *Carcinus*, *Palinurus*, *Nephrops* and *Homarus*, Mg fell from 97 to 14%, roughly in accordance with increase of activity. Antennary glands eliminated Mg, SO_4, and sometimes Ca from blood, but conserved other ions.

Lamellibranchs and gastropods accumulated K and Ca, and eliminated SO_4 to a small degree. Range of values in 6 species was 97 to 101% for Na, 107 to 155% for K, 103 to 112% for Ca, 97 to 103% for Mg, 99 to 101% for Cl, and 87 to 102% for SO_4. Considerable ionic regulation existed in cephalopods, ranges were 95 to 98% for Na, 152 to 219% for K, 94 to 107% for Ca, 102 to 103% for Mg, 101 to 104% for Cl, and 29 to 81% for SO_4. In *Eledone cirrosa* and *Sepia officinalis*, differential excretion by renal organs was important. SO_4 and Na were eliminated in quantities greater than in plasma ultrafiltrate, tending to lower these values, whereas other ions were excreted in proportions below those of an ultrafiltrate, tending to elevate their blood concentrations. Ratio of equivalents Na + K/Ca + Mg in body fluids remained at seawater figure of 3.8 in *Aurelia*, echinoderms, annelid worms, and lamellibranchs, but decreased in gastropods and cephalopods to 3.5. In decapod crustacea, owing principally to reduction of Mg, it increased from 3.8 in *Lithodes* to 9 and 12 in *Palinura* and *Astacura* spp.

2026. Robinson, K.M. and M.R. Wells. 1975. Retention of a single oral dose of cadmium in tissues of the softshell turtle, *Trionyx spinifer*. Bull. Environ. Contamin. Toxicol. 14(6):750-752.

Turtles fed orally with 2 mg Cd (as cadmium acetate) retained 9.43% of total Cd fed after 48 hrs and 4.02% after 96 hrs. Liver retained the most Cd in both instances. Concentrations, in mg Cd/kg wet wt after 48 hrs ranged from 3.45 in kidney to 20.7 in small intestine; after 96 hrs values ranged from 1.23 in stomach to 5.91 in liver. Female turtles taken from a river with high metal pollution contained Cd levels ranging from 0.19 mg/kg in small intestine to 9.87 mg/kg in kidneys. Results indicate that Cd found in effluent from treatment plants serving plating industries has little effect on health of turtles.

2027. Rocca, E. 1969. Copper distribution in Octopus vulgaris Lam. hepatopancreas. Comp. Biochem. Physiol. 28:67-82.

Octopus hepatopancreas contained 4880 ± 2549 mg copper/kg dry wt; all Cu was in the cuprous state. Ninety-six percent of Cu was bound to substances with a molecular wt (M.W.) >1500 and 50-60% to substances with a M.W. between 5000 and 30,000; only 10% was bound to substances with a M.W. of 70,000.

2028. Roeder, M. and R.H. Roeder. 1966. Effect of iron on the growth rate of fishes. Jour. Nutrition 90:86-90.

Addition of up to 7.4 mg $FeSO_4$/l enhanced growth of green swordtail Xiphophorus helleri; with platyfish X. maculatus, growth was unaffected at $FeSO_4$ levels $\leq$ 3.7 mg/l although addition of 7.4 mg $FeSO_4$/l enhanced growth. $FeSO_4$ additions reduced mortality from hatching to maturity phases. Hematocrits from both species, plus a hybrid, helleri x maculatus, were significantly higher upon treatment with 3.7 or 7.4 mg $FeSO_4$/l. Addition of 7.4 mg ferric nitrate/l had no effect. Effectiveness of Fe addition diminished as sexual maturity approached.

2029. Roesijadi, G., S.R. Petrocelli, J.W. Anderson, B.J. Presley and R. Sims. 1974. Survival and chloride ion regulation of the porcelain crab Petrolisthes armatus exposed to mercury. Marine Biology 27:213-217.

Acute toxicity of mercury, as $HgCl_2$, was determined at 7, 14, 21, 28 and 35^o/oo S. LC-50 (96 hr) values for P. armatus were 50 to 64 µg Hg/l depending on test salinities. Lower salinities decreased time to death of mercury-exposed crabs due to a greater inflow of water and therefore pollutant. Differences in survival after 96 hr due to salinity were not statistically significant. Blood chloride concentrations were hyper at low salinities and hypochloride at high salinities by acclimated crabs. The salinity isochloride to blood was 22^o/oo S. Transfer of crabs from 15^o/oo S to salinities ranging from 7 to 35^o/oo S resulted in new steady-state chloride levels within 12 hr. Exposure to 50 µg Hg/l did not alter chloride ion regulation of either acclimated crabs or crabs adjusting to new salinities.

2030. Rose, W.C. and M. Bodansky. 1920. Biochemical studies on marine organisms. I. The occurrence of copper. Jour. Biol. Chem. 44:99-112.

Whole body Cu in mg/kg wet wt was 1.5 for jelly fish (Aurelia); 2.5 for Portuguese man-of-war (Physalia); 0.0 for clams; 5.8 for crabs;

3.5 for torpedo ray; and 5.2 for sting ray. Analysis of 20 teleosts from 12 species yielded an average of 2.5 mg Cu/kg wet wt. Oysters contained Cu concentrations in mg/kg wet wt, of 35 in mantle, 34 in digestive gland, 18 in adductor muscle, and 40 in remainder (including gills), giving a total value of 34; 12.2% of Cu in oysters was in a diffusible form. In shrimp, Cu concentrations in mg/kg wet wt, were 7.3 and 2.4 for exoskeleton (including heads and tails), and meats, respectively.

2031. Rosenthal, H. and M. Fonds. 1973. Biological observations during rearing experiments with the garfish Belone belone. Marine Biology 21:203-218.

Embryology and early life history aspects are described, and also survival, ability to withstand thermal stresses, and swimming stamina. Observations on approximate high or low lethal levels of salinity after gradual adaptation indicate that young fish between 2 and 3.5 cm die when salinity falls below 2 to 3°/oo or increases beyond 55°/oo.

2032. Rosenthal, H. and K.R. Sperling. 1974. Effects of cadmium on development and survival of herring eggs. In Blaxter, J.H.S. (ed.). The Early Life History of Fish. Springer-Verlag: 383-396.

Herring eggs were incubated at 0.01, 1.0, 5.0 and 10.0 mg/l of cadmium, and in different test solutions containing mixtures of cadmium-EDTA, cadmium-zinc, and cadmium-ascorbic acid. Incubation time was reduced up to 103 hrs with increasing Cd concentration. Percentage of viable hatch was 16.3%, 82.7%, and 93.0% in 1.0, 0.1 mg/l Cd and controls, respectively. At concentrations of 5 and 10 mg/l Cd, only a few larvae hatched and those were small with long yolk sacs. Increasing Cd levels caused decreases in diameter of eyes and otic capsules; 10 mg/l Cd produced some larvae with no otic capsules. This effect was diminished in the presence of Zn and EDTA, resulting in larger larvae with larger otic capsules and higher percentage viable hatch. Uptake of Cd by herring eggs was rapid, reaching a stable level some hours after the beginning of exposure. At 5.0 mg/l, Cd concentration in whole eggs reached 18 mg/kg. Immediately before hatching, Cd levels dropped considerably, with hatched larvae containing virtually no cadmium. Eggs incubated in Cd-EDTA mixtures took up negligible amounts of Cd until the chelating capacity of EDTA was fully utilized. In the Cd-Zn (20 µg/l Zn^{2+}) study there was rapid uptake initially with quick loss during incubation. Primary site of cadmium uptake was at egg capsule surface, reaching 85 mg/kg in chorion when incubated in 5 mg/l Cd solutions. This produces a change in the physico-chemical properties of chorion, resulting in shortened incubation time, lower percentage viable hatch, and smaller larvae. The ionic form of cadmium in seawater is important for action of toxicity mechanisms.

2033. Ross, I.S. and K.M. Old. 1973. Mercuric chloride resistance of Pyrenophora avenae. Trans. Brit. Mycol. Soc. 60:293-300.

Isolates of the fungi P. avenae from naturally infested seed which had not been exposed to mercury compounds were found to be either resistant or sensitive to $HgCl_2$. Isolates surviving on not more than 50 mg $HgCl_2$/kg were considered sensitive and those surviving on ≥ 75 mg/kg were regarded as resistant. Ultrathin sections of mycelium treated with 100 mg $HgCl_2$/kg prior to fixation with potassium permanganate did not show electron-transparent areas; the nuclear envelope had a more rounded appearance than those not treated with $HgCl_2$ suggesting that nucleus is a binding site of $HgCl_2$. Nuclei of resistant isolates treated with 50 mg $HgCl_2$/kg were similar to untreated mycelium, but nuclei of sensitive isolates similarly treated with Hg more nearly resembled those of mycelium treated with 100 mg $HgCl_2$/kg. Authors concluded that Hg was toxic to nuclei of sensitive isolates but not resistant isolates. No correlation was evident between the production of red pigment (a mixture of 1,4,5,8-tetrahydroxyanthraquinones and capable of chelating Hg), and resistance to $HgCl_2$.

2034. Ross, I.S. and K.M. Old. 1973. Thiol compounds and resistance of Pyrenophora avenae to mercury. Trans. Brit. Mycol. Soc. 60:301-310.

Approximately equal quantities of non-protein thiol compounds were detected in both sensitive and resistant strains of P. avenae to mercury. Since this could be due to problems in extracting and determining thiol content, thiol reagents were used to inactivate intracellular thiols. Resistance of mycelium and conidia to Hg was reduced by treatment with iodoacetic acid. Oxidation of thiols within conidia by diamide also greatly reduced resistance. It was suggested that a pool of thiol compounds within the cells is responsible for Hg resistance.

2035. Rothstein, A. 1959. Cell membrane as site of action of heavy metals. Federation Proc. Fed. Amer. Soc. Exp. Biol. 18:1026-1038.

Topics discussed included role of cell membranes in primary reactions with environmental metals; role of physiologically inert cytoplasmic substances that bind with and affect toxicity of metals;

symptoms of membrane vs cytoplasmic toxicity; and the chain of events between chemical interaction and physiological result. Examples are presented of action of Hg, U, Mn, K, Mo, Na, and Ca, on cell membranes of mammals, bacteria and yeasts.

2036. Rucker, J.B. and J.W. Valentine. 1961. Salinity response of trace element concentration in *Crassostrea virginica*. Nature 190:1099-1100.

Shells of oysters collected between Massachusetts and Texas were analyzed for trace metal content to determine correlations between elemental concentrations and ambient thermosaline regimes. Salinities ranged from 13.3 to 30.4^{o}/oo and metal content ranged from 1964 to 2744 mg/kg for Mg, 1142 to 1648 mg/kg for Sr, 21 to 227 for Mn, and 2064 to 3264 for Na. No significant correlation with temperature was demonstrable and neither Sr, Mg, B nor Cu were related to either temperature or salinity. Significant correlations between elemental concentrations and salinity were demonstrated for Mn and for Na. If individual Sr and Mg concentrations are combined and correlated with salinity the coefficient is significant; significant correlation of Mg, Mg plus Sr, Mn and Na with salinity was demonstrated.

2037. Ruesink, R.G. and L.L. Smith, Jr. 1975. The relationship of the 96-hour LC_{50} to the lethal threshold concentration of hexavalent chromium, phenol, and sodium pentachlorophenate for fathead minnows (*Pimephales promelas* Rafinesque). Trans. Amer. Fish. Soc. 104(3):567-570.

Short-term bioassays were conducted using adult minnows vs Cr^{+6}, phenol, and sodium pentachlorophenate at 15 C and 25 C. LC-50 (96 hr) values for Cr were 52 mg/1 at 15 C and 37 mg/1 at 25 C; a similar pattern was observed at 48 hrs. The lethal threshold concentration was not a constant multiple of the LC-50 (96 hr) value for any toxicants examined.

2038. Rummel, W., H.-J. Bielig, W. Forth, K. Pfleger, W. Rudiger and E. Seifen. 1967. Absorption and accumulation of vanadium by tunicates. Protides Biol. Fluids Proc. Colloq. Bruges 14: 205-210.

Accumulation of vanadium in blood cells (1.2 to 1.8 μg V/mg dry wt) of *Ciona intestinalis* is preceded by a specific absorption process. The site of absorption is the one-layer epithelium of the branchial net. The absorption of V is a biochemical process which is highly temperature-dependent (increasing with rising temperature) and which is inhibited by ouabain, an inhibitor of the membrane ATPase system. Phosphate and arsenate were shown to inhibit V absorption, whereas chromate, niobate, molybdate and iron were incapable. V can be bound by blood plasma of C. intestinalis

2039. Ruohtula, M. and J.K. Miettinen. 1975. Retention and excretion of ^{203}Hg-labelled methylmercury in rainbow trout. Oikos 26: 385-390.

Elimination of Me-Hg-203 by whole trout Salmo gairdneri, followed a bi-exponential equation. Biological half-time of Me-Hg at 16-19 C varied from 202 to 516 days depending on retained dose and water temperature. At 16-19 C, it was 204 d with a retained dose of 3 ug Hg/kg and 348 d with a retained dose of 0.06 mg Hg/kg. At 0.5-4 C retained doses of 0.05-0.10 took 516 d for half-time excretion. Ionic Me-Hg absorbed via gills was excreted faster (TB 1/2 = 268 d) than ionic Me-Hg administered per os (TB 1/2 = 320 d) or injected intramuscularly (TB 1/2 = 319 d) and this is attributed to an increase in protein-bound mercury.

2040. Russel, G. and O.P. Morris. 1970. Copper tolerance in the marine fouling alga Ectocarpus siliculosus. Nature 228:288-289.

Differential responses to dissolved copper by a brown alga E. siliculosus, may be associated with habitats from which populations were taken. Five-week bioassays utilizing different concentrations of Cu as $CuCl_2$, showed that E. siliculosus from an uncontaminated rocky shore had a critical toxicant concentration (concentration at which there is no increase or decrease in plant volume) of 0.05 mg Cu/l. Two populations from hulls of different ocean-going freighters treated with copper-based antifouling bottom preparations had critical toxicant concentrations of 0.5 mg Cu/l each.

2041. Russell, G. and O.P. Morris. 1972. Ship-fouling as an evolutionary process. Proc. 3rd Int. Congress on Marine Corrosion and Fouling, Wash. D.C., Oct. 2-9:719-730.

Populations of Ectocarpus siliculosus, a brown alga, collected from ship hulls and Cu-contaminated regions, were more Cu resistant than populations from uncontaminated rocky shores. Cu tolerance arose by spontaneous mutation from an otherwise Cu-sensitive strain, thereby producing plants of high potential fouling ability. Cu tolerance heritability was established by culture of successive generations.

2042. Russell, P. 1955. Inactivation of phenyl mercuric acetate in groundwood pulp by a mercury-resistant strain of Penicillium roqueforti Thom. Nature 176(4493):1123-1124.

A mercury resistant strain of P. roqueforti absorbed phenyl mercuric acetate from nutrient media and reduced the concentration of biologically active Hg to nil, allowing invasion by other non-tolerant bacterial species.

2043. Ruthven, J.A. and J. Cairns, Jr. 1973. Response of fresh-water protozoan artificial communities to metals. Jour. Protozool. 20:127-135.

An artificial freshwater protozoan community was subjected to different concentrations of Zn and Cu in a test system through which pond water flowed continuously. Although percent survival of colonizing species exposed to Cu or Zn fluctuated greatly at each concentration, the range of toxicity for each compound allowed comparison of protozoa with other organisms with respect to resistance to heavy metal toxicity. Individual protozoan species also were exposed for 3 hr to Zn, Cu, Cr, phenol, Pb, Mn, Co, HNO_3, acetic acid, Al, Sn, and HCl to derive time to death curves. Protozoa tested appeared to be more resistant than Daphnia to phenol, $K_2Cr_2O_7$, and Cu; however, some species were more sensitive than Daphnia to Zn, nitric acid, and HCl. This suggests that sensitivity of protozoa to toxicants may be either more or less than that of macroinvertebrates and that information does not suffice to predict sensitivity. Moreover, the relative sensitivity of protozoa to various toxicants will not always be the same, i.e. species X may be twice as tolerant to a toxicant as species Y but its relative sensitivity may be quite different for another toxicant. Concentrations of selected metals salts lethal (or tolerated) by 13 protozoan species, in mg/l metal, ranged as follows: Cr^{+6}, 160 to 5000 (>18 to 1000); Cu, 0.056 to 500 (0.024 to 18.0); Pb, 56 to >1000 (5.6 to 1000); Mn, 3.2 to >32 (0.65 to 3.2); Zn, 5.6 to >1000 (0.56 to 5000); Co, >2500 to >5000 (1000 to 2500); Al, 2.4 to >1000 (1.0 to 1000); Sn, 10 to 32 (7.5).

2044. Ryder, J.A. 1881(1882). Notes on the breeding, food, and green color of the oyster. Bull. U.S. Fish Comm. 1:403-419.

A brief account of the natural history and cultivation of oysters, as known at that time, is given. Speculation is made as to source of green coloration found in some oysters; proposed causes include spores of green algae Ulva; the green microscopic plant Navicula ostrearia; algous parasites or diatoms collecting in the animal tissues (but was found to be green blood cells); and that "blood cells imbibing the color from the tinged nutritive juices transuded through the walls of the alimentary canal acquired the color of the food which has been dissolved by the digestive fluids." That copper could be the causative agent was totally discredited for the quantity of copper needed to produce green organs would "without a doubt be as fatally poisonous to the oyster as to a human being."

2045. Ryndina, D.D. 1973. Extraction of strontium-90 from seawater by some high molecular weight compounds of brown algae. Hydrobiological Jour. 9:16-20.

Data on accumulation and fixation of Sr-90 by live, killed, and decomposing *Cystoseira barbata* thalli are presented; changes in content of alginic acids and quantity of metals released during detritus formation following acid digestion are shown. There is a 3 to 5X decrease in Sr-90 accumulation in *C. barbata* upon decomposition and detritus formation; this does not significantly reduce content of alginic acids in detritus. Metals equivalent to concentration of alginic acids were extracted from *C. barbata* when treated with dilute HCl. Increased HCl concentrations sharply altered this relationship with no significant decomposition of alginic acids occurring in such treatment. Between 81 and 91% of Sr-90 in *C. barbata* was bound to compounds possessing ion-exchange properties or capable of dissolving when treated with weak HCl.

2046. Ryndina, D.D. and G.G. Polikarpov. 1974. Role of *Cystoseira barbata* (Good et Wood) AG. polysaccharides in the extraction of some radionuclides from seawater. Hydrobiological Jour. 10(5):61-65.

Removal of fucoidan from *Cystoseira barbata* did not affect uptake of Mn-54, Y-91, or Ce-144 by decomposing alga. However, fucoidan may act to concentrate Ca-45 and Sr-90 and stimulate Sr-90 fixation by alginic acids. Sharp decrease in Sr-90 build-up factors in decomposing *Cystoseira* may be due to decrease in sorption properties of its individual polysaccharides, especially alginic acids, following changes in pH of intracellular fluids. *Cystoseira* alginic acids and algulose participate in concentration of Y-91 and Ce-144 from seawater.

2047. Sabodash, V.M. 1974. Survival rate of grass carp larvae after exposure to zinc sulfate. Hydrobiological Jour. 10:77-80.

At water hardness of 4.4 to 4.9 meq/l, mean percent survival of carp larvae (*Ctenopharyngdon idella*) during exposure for 25 days to zinc sulphate water levels of 0.05, 0.5, and 5.0 mg/l was higher than controls (64.2, 69.5 and 61.6, respectively, compared to 58.7%). At this hardness, addition of zinc salts at 0.05 and 0.5 mg/l also improved size of larvae. Variability of length and weight and number of individuals lagging in development and growth were less than in control. The 5.0 mg/l concentration adversely affected larval size and weight. Addition of Zn salts to water with hardness of 8.2 to 8.7 meq increased 25 day survival rate to 71.2%, 80.7% and 69% at concentrations of 0.05, 0.5 and 5.0 mg/l, respectively, as compared to 65.0% in the control. Differences in responses to Zn salts in water of varying hardness suggest that Zn ions have a more stimulatory effect in water with a high calcium content. Zinc has a selective effect in zones affecting calcification of bony tissue.

2048. Sadolin, E. 1928. The occurrence of arsenic in fish. Dansk. Tids. Farmoci. 2:186-200. (In Danish, English summary)

In 2 analyses of codfish muscle tissue, values of 0.4 and 0.8 mg As/kg were determined. Liver contained 0.7 and 3.2 mg As/kg; and cod-liver oil between 3.0 and 4.5 mg As/kg. Attempts were made to concentrate the oil-soluble arsenic compounds. From 6700 cc cod-liver oil containing 26 mg As, a 2 cc extract was obtained containing 2 mg As. The oil-containing muscular tissue from an eel was extracted whereby all arsenic was removed from tissue and 0.6 mg As/kg was found in oil. Similar experiments with herring showed a content of 2.0 mg As/kg in muscle tissue and 9.0 mg As/kg in oil.

2049. Saenko, G.N., M.D. Koryakova, V.F. Makienko and I.G. Dobrosmyslova. 1976. Concentration of polyvalent metals by seaweeds in Vostok Bay, Sea of Japan. Marine Biology 34:169-176.

Spectrophotometric methods were used to measure contents of Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Mo and Zn in 16 species of red, brown, and green seaweeds and 2 species of higher water plants collected from intertidal and sublittoral zones of Vostok Bay, Sea of Japan. Some species displayed capability for increased accumulation of selected groups of several metals. Ptilota filicina concentrates Ti, V, Mn, Fe, Ni, Cu, Zn, and Mo; Polysiphonia japonica Ti, V, Mn, Fe, Zn, Mo, and Cr; Rhodomela larix Ti, V, Mn, Fe, Ni, Zn, and Cr; Agarum cribrosum Ti, V, Mn, Fe, Ni, Zn, and Cr; Ulvaria splendens Ti, V, Mn, Fe, Ni, and Cu; Ulva fenestrata Mn, Fe, Ni, and Cu; Enteromorpha prolifera Mn, Co, Zn, Mo, and Cr; Codium yessoensis V, Mn, Fe, Zn, and Cr; Zostera asiatica Ti, Mn, Ni, and Mo; Phyllospadix iwatensis Ti, V, Mn, Fe, and Zn. The contents of the metals studied in seawater and the accumultion coefficients were also determined. The variation range is extremely high both for the seaweed species and metals investigated. Maximum coefficients were noted for the following: Mn, 1.8×10^5; Ti, 4.4×10^4; Fe, 2.4×10^4; and Cr, 1.2×10^6.

2050. Saiki, M. and T. Mori. 1955. Studies on the distribution of administered radioactive zinc in the tissues of fishes I. Bull. Jap. Soc. Sci. Fish. 21(8):945-949.

Radioactivity levels in c/m/g of tissue of clam Meretrix following immersion for 3 days in seawater containing 200,000 c/m/l Zn-65 were: gill, 500; viscera without liver, 270; mantle, 260; liver, 250; adductor muscle and siphon, 170; and foot, 130. After 22 days in water containing 45,000 c/m/l Zn-65, carp Cyprinus contained 285 c/m/l in gill, 50 in skin and caudal fin, 65 in scales, 5 in vertebrae, 27 in intestine, 2 in gall-bladder, 26 in hepatopancreas, 299 in kidney, 57 in heart and 3 in muscle.

Respective radioactivity values, in c/m/g raw tissue of carp 45 to 48 hrs after intramuscular injection of 5,000 c/m Zn-65, 12,000 c/m Sr-90 or 27,000 c/m Cs-137, were 1180 (Zn), 163 (Sr), and 2,200 (Cs) for kidney; 251, 44, and 427 for hepatopancreas; 173, 0, and 2,325 for heart; 121, 14 and 510 for intestine; 119, 352 and 756 for gill; 87, 1349, and 522 for scale; 86, 569, and 832 for caudal fin; 51, 0, and 669 for gall bladder; 31, 60, and 349 for skin; 29, 137, and 301 for vertebra; and 9 (Zn), 20 (Sr), and 130 (Cs) for muscle.

2051. Saiki, M., S. Okano and T. Mori. 1955. Studies on the radioactive material in the radiologically contaminated fishes caught at the Pacific Ocean in 1954. Bull. Jap. Soc. Sci. Fish. 20(10):902-906. (In Japanese, English abstract)

Highest concentrations of radioactivity were found in viscera, particularly spleen, kidney and liver, with decreasing amounts in heart, gill, intestine, and reproductive organs; very little was detected in muscles and bone. Some radioactive material could be removed from raw meat with water or 0.5% EDTA-Na solution. Active substances in fish were chiefly composed of the radioisotopes of Al, Fe, Zn, Co, and Ni; relatively little Sr or Ca was detected.

2052. Saliba, L.J. and M. Ahsanullah. 1973. Acclimation and tolerance of Artemia salina and Ophryotrocha labronica to copper sulphate. Marine Biology 23:297-302.

Brine shrimp A. salina and polychaete O. labronica were acclimated in seawater with copper sulphate at concentrations of 0.1, 0.05, and 0.025 mg Cu^{2+}/l, for 3 and 2 generations, respectively. Adults and larvae of A. salina showed a greater tolerance to 1 mg Cu^{2+}/l after acclimation compared to controls of the same age, although this tolerance diminished in successive generations. The acclimation effect was less marked in O. labronica. In both species, tolerance to concentrations >10 mg Cu^{2+}/l was not enhanced. Growth-rate inhibition and an adverse effect on reproduction was observed for both species, in some instances in direct relationship to the acclimation concentration. For A. salina, authors suggest that a certain tolerance to Cu may be acquired through exposure to low concentrations.

2053. Saliba, L.J. and R.M. Krzyz. 1976. Effects of heavy metals on hatching of brine-shrimp eggs. Marine Poll. Bull. 7:181-182.

Addition of Cu, Fe, and Zn (as sulphates) caused decreased hatch of brine-shrimp Artemia salina eggs with increasing concentrations. With Pb (as acetate), decrease in hatch remained constant. Taking concurrent seawater controls as 100%, percentage hatch after 3 days exposure to 5 mg/l metal were: Cu, 15%; Pb, 65%; Fe, 46%; and Zn, 15%.

2054. Saliba, L.J. and R.M. Krzyz. 1976. Acclimation and tolerance of Artemia salina to copper salts. Marine Biology 38:231-238.

Brine shrimp were acclimated in seawater with cupric chloride, acetate, carbonate, and sulphate, each at concentrations of 0.1, 0.05, and 0.025 mg Cu/l. When compared to controls, growth inhibition was observed in all four compounds generally in direct relation to concentration. Growth was least in sulphate, and increased progressively in chloride, acetate and carbonate, in that order. No inhibition was observed in carbonate at 0.025 mg Cu/l. In toxicity tests, 2-week old larvae from each solution were exposed to concentrations of 10, 7.5, 5, 2.5 and 1 mg Cu/l of the same compounds, together with unacclimated larvae of the same age. Similar tests were held with 6-week old adults acclimated in: 0.1 mg Cu/l (chloride, acetate and sulphate) using the same concentrations; and in 0.5 mg Cu/l (carbonate), using 150, 125, 100, 75, and 50 mg Cu/l. Toxicity to unacclimated larvae and adults differed with compounds, carbonate being the least toxic, followed by sulphate, chloride and acetate in increasing order. Larvae acclimated in chloride (0.025 mg Cu/l) and sulphate (0.1 and 0.5 mg Cu/l) showed an increased tolerance to 1 and 2.5 mg Cu/l compared to untreated controls; tolerance was not enhanced from 5 mg Cu/l upwards. In both compounds, adults acclimated in 0.1 mg Cu/l showed increased tolerance to concentrations between 1 and 7.5 mg Cu/l compared to controls. Larval mortality in carbonate was below 50% in all test solutions; adults acclimated at 0.5 mg Cu/l showed an increased tolerance to 50 mg Cu/l compared to controls. Considerable precipitation occurred with high levels of this compound, thus affecting the "final" concentrations. No acclimation effect was observed in acetate for either larvae or adults. It is suggested that in A. salina, copper toxicity depends on the particular form of the metal, and that this difference is manifested in growth inhibition and in potential acquisition of increased tolerance through exposure to low concentrations.

2055. Saltman, P. and H. Boroughs. 1960. The accumulation of zinc by fish liver slices. Arch. Biochem. Biophys. 86:169-174.

Zinc can be accumulated by Tetraodon hispidus liver cells against an apparent seven-fold concentration gradient via a passive mechanism not directly coupled to metabolic energy. Kinetic studies suggest that this process consists of a first-order sorption of Zn to binding sites on or within the cell. Although the binding site is not specifically characterized, it is profoundly altered by changes in temperature, pH, and chemical environment.

2056. Sandholm, M. 1973. Biological aspects of selenium: Uptake of selenium by SH-groups and different organic materials in the ecosystem. Thesis, Dept. Medicine, Coll. Veterinary Medicine, Helsinki, Finland. 35 pp.

Although soils and plants in Finland were generally low in selenium, high levels of Se in plants are associated with poisoning of livestock. An important natural source of selenium may be fish which in turn obtain Se from plankton. Phytoplankton such as Scenedismus dimorphus, actively take up selenomethionine; zooplankton absorb selenite directly from the water. In animals, selenite is metabolized by erythrocytes, bound by carrier proteins associated with plasma albumin, and then transported through the body. Selenite is bound to plasma albumin using reduced glutathione. The active form of Se may be the selenide located in non-haem-iron proteins.

The beneficial action of selenite may be due to its effect on the enzyme glutathione peroxidase. Glutathione is necessary in maintaining erythrocyte GSH, preventing oxidative damage. When erythrocytes were incubated in selenite, Se was fluxed into cells within 1-2 minutes and thereafter pumped out by a GSH dependent system. Se induced electron flow from higher energy states to lower levels, thereby decreasing sulfhydryls and increasing oxygen consumption. When toxic amounts of Se were introduced, Se in cell proteins and organelles normally present in small amounts became disorganized with electrons transferred in an uncontrolled way towards oxygen. The "charge transfer" capacity of Se may be enhanced by hypervalent bonding. Se is excreted by urinary, faecal, and respiratory routes.

2057. Sandifer, P.A., J.S. Hopkins and T.I.J. Smith. 1975. Observations on salinity tolerance and osmoregulation in laboratory-reared Macrobrachium rosenbergii post-larval(Crustacea: Caridea). Aquaculture 6:103-114.

The tolerance of post-larval prawns to gradual and rapid increases in salinity was determined. Mortalities occurred at salinities around 25°/oo and increased rapidly at levels $\geq$30°/oo in both cases. However, acclimation substantially increased survival time at 35°/oo. Freezing point depressions of blood were measured from laboratory-reared post-larvae and juveniles exposed to various salinities from freshwater to approximately 35°/oo. Blood concentration was hyperosmotic to medium at salinities from freshwater to about 17-18°/oo and hypoosmotic at higher salinities. Post-larvae maintained a nearly constant blood concentration over a wide range of external salinities (freshwater to about 27-30°/oo). Osmoregulatory mechanisms failed at salinities $\geq$30°/oo, and thereafter blood concentration paralleled that of medium. Blood concentrations of juvenile shrimp grown for 5 months at salinities from freshwater to about 15°/oo closely resembled those of post-larvae.

The osmoregulatory performance of young M. rosenbergii is generally similar to that of other brackish water animals, but in their ability to hyperosmoregulate effectively in freshwater they more closely resemble freshwater species. It is suggested that M. rosenbergii may be able to conserve salt in dilute media by producing blood-hypoosmotic urine. A stress symptom often preceded death of post-larvae in high salinities; animals changed gradually from nearly transparent to opaque white and then died, usually within a day or so.

2058. Sandow, A. and A. Isaacson. 1966. Topochemical factors in potentiation of contraction by heavy metal cations. Jour. Gen. Physiol. 49:937-961.

Low concentrations (about 0.5 mM) of Zn^{2+}, Be^{2+}, Ba^{2+}, Cd^{2+}, Ni^{2+}, Cu^{2+}, Pt^{4+}, and 0.5 um of UO_2^{2+}, potentiate the twitch of frog sartorius and toe muscles by prolonging the active state of contraction. Magnesium, Ca^{2+}, and Hg^{2+} decrease contraction, and Sr^{2+} has variable effects. The degree of potentiation is a roughly S-shaped function of p (metal^{2+}), suggesting that each metal binds to a ligand of the muscle fiber, representative apparent affinity constants being: UO_2^{2+}, 5 x 10^6; Zn^{2+}, 2.8 x 10^5; and Cd^{2+}, 2 x 10^4. UO_2^{2+} potentiation effects are rapidly reversed by PO_4, and Zn^{2+} and Cd^{2+} effects by EDTA, PO_4, and cysteine. The rapidity of these reversals by nonpenetrating EDTA and PO_4, and the fact that heavy metal ions evidently potentiate by prolonging the action potential, indicate that metal potentiators exert their primary action at readily accessible (i.e., plasma and T tubular) membrane sites. Relatively slow kinetics of development of potentiation, and even slower reversal of it in pure Ringer's solution, indicate that metal ions are bound to connective tissue, as well as to muscle fibers, to the amount of 1.0 uM/g for Zn, and 100 times that for UO_2^{2+}. The binding effects at the readily accessible membrane sites evidently impairs delayed rectification and thus modifies the action potential and excitation-contraction coupling so as to cause potentiation; this does not occur with anions such as NO_5. SH is excluded, and PO_4 and imidazole are possibilities, as the membrane ligand binding the potentiating metal ions.

2059. Sano, K. and H. Mohri. 1976. Fertilization of sea urchins needs magnesium ions in seawater. Science 192:1339-1340.

When sea urchin eggs were inseminated in seawater free of magnesium, the fertilization rate was very low. Spermatozoa that had been treated with egg jelly to induce the acrosome reaction also failed to fertilize eggs in Mg-free seawater. These results indicate that Mg is indispensable for some process or processes at fertilization, such as membrane fusion or sperm penetration.

2060. Sappington, C.W. 1969. The acute toxicity of zinc to cutthroat trout (*Salmo clarki*). M.S. Thesis, University of Idaho Graduate School. 25 pp.

In static water with a hardness of 23.9 mg/l as $CaCO_3$, and pH 7, LC-50 (24, 48 and 96 hr) values of zinc, for trout, were 0.62, 0.27 and 0.09 mg/l, respectively. In a recirculating, flowing-water bioassay, the LC-50 (24 hr) value of Zn was 0.42 mg/l.

2061. Sarata, U. 1938. Studies in the biochemistry of copper. XXX. Seasonal changes in the amount and distribution of copper in tissues of the cultivated bull-frog. Japan. Jour. Med. Soc. 4:65-69.

Blood copper was highest at the end of winter, substantially lower in the spring, increases somewhat with egg laying, and lowest in the fall. Water balance and changes associated with breeding were considered the most probable causes. A similar pattern, but of reduced magnitude, was established for liver (the primary storage organ for Cu). Fat contained reduced levels of copper (by half) during spring and breeding seasons. Eggs contained comparatively high levels of copper.

2062. Sargent, D.F. and C.P.S. Taylor. 1972. The effect of cupric and fluoride ions on the respiration of *Chlorella*. Canadian Jour. Bot. 50:905-907.

Respiration of the alga *C. pyrenoidosa* was not decreased by 760 mg F/l or 512 mg Cu^{2+}/l, but simultaneous addition of both stopped oxygen uptake. Authors conclude that Cu alone does not inhibit a dissimilation pathway distinct from glycolysis.

2063. Sarot, D.A. and A. Perlmutter. 1976. The toxicity of zinc to the immune response of the zebrafish, *Brachydanio rerio*, injected with viral and bacterial antigens. Trans. Amer. Fish. Soc. 105:456-459.

Zebrafish were injected with antigens prepared from infectious pancreatic necrosis virus (IPNV) or from the bacterium *Proteus vulgaris*. Zinc, present at 0.3 mg/l (1/10th the 96 hr LC-50 value) appeared to suppress the immune response against *P. vulgaris* but not against IPNV. Two weeks after second injection, IPNV-injected fish produced antibody titers of 32 in both zinc-treated and non-zinc-treated groups, but *P. vulgaris*-injected fish produced antibody titers of 128 and 32 in non-zinc-treated groups and 0 in zinc-treated groups.

2064. Sastry, V.W. and Y.M. Bhatt. 1965. Zinc content of some marine bivalves and barnacles from Bombay Shores. Jour. Indian Chem. Soc. 42:121-122.

The following mean zinc concentrations, in mg/kg wet wt, were found in samples collected from Bombay coast: 11 for clam *Katelysia marmorata*, 14 for clam *Meretrix meretrix*, 11 for mussel *Mytilus viridis*, 254 for rock-oyster *Crassostrea cucullata*, 203 for backwater oyster *C. madrasensis*, and 71 for barnacle *Balanus amphitrite communis*.

2065. Sato, S., Y. Miyata and S. Kunitomi. 1976. Physical properties of "narutowakame" and its alginate and metal contents. Bull. Jap. Soc. Sci. Fish. 42(3):337-341.

Water soluble alginate derived from brown seaweed, *Undaria pinnatifida*, contained elemental levels up to 40 mg/kg for Na and K, 20 for Ca and 30 for Mg. Each element decreased to <10 mg/kg upon ash-treatment, an important step in processing of "narutowakame," a Japanese food substance. Residues contained levels, in mg/kg, of ∿25 for Na and K and up to 250 for Ca and 200 for Mg. Ash-treatment increased Ca levels to 700 mg/kg, but did not affect other elements. From tensile strength studies, authors concluded that hardness of "narutowakame" is due to formation of water insoluble Ca alginates during ash-treatment.

2066. Saward, D., A. Stirling and G. Topping. 1975. Experimental studies on the effects of copper on a marine food chain. Marine Biology 29:351-356.

Copper at levels of 10, 30, and 100 ug Cu/l were applied to a marine food chain consisting of phytoplankton, the clam *Tellina tenuis*, and juvenile flatfish *Pleuronectes platessa*. Accumulations were dose-dependent and in no case was a plateau concentration reached. Most of the added dose was taken up by sand; accumulations in clam shell were negligible. However, high levels were found in clam flesh, where concentrations after 100 days were 50, 270, 470, and 1100 mg Cu/kg dry flesh for added dose concentrations of 0, 10, 30, and 100 μg Cu/l, respectively. There was no accumulation of Cu in fish muscle, but accumulations in viscera after 100 days were 30, 71, 147, and 567 mg Cu/kg dry flesh for dose concentrations of 0, 10, 30, and 100 μg Cu/l, respectively. All doses reduced both standing crop and rate of photosynthesis per unit of chlorophyll a. All dose concentrations adversely affected clam condition, with effect most marked during deposition of winter reserves. Siphons of *Tellina*, which are important food items for *Pleuronectes*, showed a weight decrease when exposed to 30 and 100 μg Cu/l. For fish, all Cu doses resulted in reduced growth, but there was no significant change in condition or biochemical composition. However, ash weight of fish exposed to copper was significantly higher than controls.

2067. Sayler, G.S., J.D. Nelson, Jr. and R.R. Colwell. 1975. Role of bacteria in bioaccumulation of mercury in the oyster *Crassostrea virginica*. Applied Microbiol. 30(1):91-96.

Uptake of Hg-203 by oysters held under control conditions was compared with that of Hg-203 uptake by oysters under similar conditions except that Hg-accumulating and Hg-metabolizing species of *Pseudomonas* were added to the test oysters. After 4 days in seawater containing 10 ug of Hg-203 Cl_2/l, oysters without bacteria contained 4 ug Hg/kg wet wt in mantle fluid, 200 in mantle, 647 in gills, 216 in viscera, and 56 in adductor muscle, with a total content of 201 ug Hg/kg wt tissue. Oysters with a Hg-reducing strain of *Pseudomonas* accumulated 9 ug Hg/kg wt tissue in mantle fluid, 511 in mantle, 1747 in gills, 463 in viscera, 133 in adductor muscle, and 312 in whole oyster. Oysters held with a Hg-accumulating strain of *Pseudomonas* contained 12 ug Hg/kg wt tissue in mantle fluid, 405 in mantle, 2850 in gills, 335 in viscera, 161 in adductor muscle, and 463 in whole oyster. The major portion of Hg-203 in water was associated with microparticulate fraction corresponding to a rise in total viable count of *Pseudomonas*. Authors concluded that whole oyster accumulation of mercury was more than doubled in presence of Hg-resistant bacteria.

2068. Schell, W.R. and R.L. Watters. 1975. Plutonium in aqueous systems. Health Physics 29:589-597.

A review of current knowledge of plutonium in aquatic environments is presented. Limited data indicate that low environmental levels are present. Concentration factors are highest in plankton, and decrease with increasing organism complexity. Recent studies of water, sediment, algae, fish, molluscs, echinoderms, crustacea, and detritus at Bikini and Eniwetok Atolls indicate that Pu exists in the particulate, soluble, and colloidal physical-chemical states. Radioplutonium species, even 16 years post-initial contamination, are still being injected into water column from sediments, indicating an active biogeochemical cycle. Concentrations of plutonium in vertebrates and invertebrates measured at Eniwetok were low and ranged from 0.001 to 0.2 pCi/g wet in fish muscle.

2069. Scott, D.M. and C.W. Major. 1972. The effect of copper (II) on survival, respiration, and heart rate in the common blue mussel, Mytilus edulis. Biol. Bull. 143:679-688.

After 7 days, 55% of mussels held in 0.2 mg/l of Cu^{2+} (initial concentration) died; only 5% were dead at 0.1 mg/l of Cu^{2+}; controls exhibited 1% mortality over the same time period. At 10 mg/l of Cu^{2+}, valves were closed immediately after addition of copper and remained closed for at least 15 hours, at which time this portion of the study was discontinued. At 1.0 mg/l of Cu^{2+}, mussels shut down for about 15 minutes; afterwards, valves were opened and rate of oxygen consumption was 184 µl/hr; approximately 90 minutes after copper addition there was a sudden increase in respiration until rate approached that of controls (578 µl of oxygen per hr). At 0.5 mg/l of Cu^{2+} there was no initial shutdown, but a recovery similar to that of 1.0 mg/l was observed. At 0.3 mg/l there was neither a shutdown or recovery. At 0.2 mg/l of Cu^{2+} the change in respiration over 2 hours at 10 C was not significantly different from controls. No change in heart beat rate from controls was noted at 0.2 mg/l of Cu^{2+}, but at higher concentrations a general dose response is clearly apparent within one hour. It is suggested that organically bound Cu does not provide toxic levels of free Cu. Some organisms will be damaged by free Cu on initial binding, as this is considered the toxic step. But members of the food chain may accumulate extraordinary levels of organically bound copper without apparent effect. Authors conclude that free copper and not total copper in a marine ecosystem is probably the pertinent parameter of toxicity.

2070. Scott, D.P. 1974. Mercury concentration of white muscle in relation to age, growth, and condition in four species of fishes from Clay Lake, Ontario. Jour. Fish. Res. Bd. Canada 31:1723-1729.

Studies of walleye Stizostedion vitreum, northern pike Esox lucius, white sucker Catostomus commersoni, and lake whitefish Coregonus clupeaformis from each of 4 areas of a highly Hg-contaminated lake showed that larger fish have greater white muscle Hg concentration within species and within populations. Older fish and faster-growing fish were generally more contaminated, while relatively heavier fish were less contaminated, subject to the above species-areas restrictions. Statistical analyses indicated profound within-species differences between samples from all areas. There was no correlation between these differences and sediment Hg values. There are significant interactions between age and growth, and age and condition.

2071. Scott, R. 1954. A study of caesium accumulation by marine algae. Proc. 2nd Radioisotope Conf. 1:373-380.

Fucus vesiculosus accumulated Cs-134 by a concentration factor (C.F. = counts per g dry wt/counts per g seawater) of 50 in 45 days when maintained in natural and artificial seawater. Exclusion of K and an equivalent addition of Na resulted in a CF of 200 in 25 days. Cs-134 uptake by *Rhodymenia palmata* was light dependent, but no region of the visible spectrum was disproportionately effective in promoting uptake. Treatment of *R. palmata* with 0.001 M sodium azide, 0.001 M potassium cyanide or CO_2 exclusion, resulted in diminution or cessation of Cs-134 uptake. A lethal dosage of 0.001 M dinitrophenol resulted in total Cs-134 release. Healthy *R. palmata*, which had absorbed Cs-134, lost no radioactive material over several weeks when transferred to natural seawater. For *R. palmata*, highest concentrations occurred in stipo-frondal zone. In *Laminaria digitata* uniform radioactivity per unit area was found from stipo-frondal zone to tip.

2072. Severy, H.W. 1923. The occurrence of copper and zinc in certain marine animals. Jour. Biol. Chem. 55:79-92.

Crustaceans, molluscs, teleosts, echinoderms, coelenterates, and marine mammals (16 species in all) were analyzed for Cu and Zn. Highest concentration of copper in any sample was 19.6 mg/kg wet wt in shrimps and the lowest was <0.00 mg/kg in shell of mussel, and spleen and liver of sea lion. All other copper values ranged between 0.56 and 4.0 mg/kg. Zinc was present in all samples with values ranging from 2.11 mg/kg in sea urchin to 64.9 mg/kg in oyster (zinc content of California oyster is much lower than Eastern oyster). Marine mammals (sea lion, whale) do not carry copper to any extent; copper in the sea food eaten does not appear to be accumulative; zinc was present in all tissues examined, but amount is less than for oysters. Copper is present in lower forms of sea animals as an oxygen carrier in place of the iron of mammals; environment does not seem to change the sea lion and whale in this respect. The function of the zinc had not been clearly worked out.

2073. Seymour, A.H. 1966. Accumulation and loss of zinc-65 by oysters in a natural environment. Proc. Symp. Disposal Radioactive Wastes into Seas, Oceans and Surface Waters. Int. Atom. Ener. Agen., Vienna, 16-20 May 1966: 605-619.

Accumulation and loss of Zn-65 by oysters was determined by cross-transplanting *Crassostrea gigas* from/to Puget Sound or Hood Canal, where Zn-65 is virtually absent, to/from Willapa Bay, which contains from 0.0036 to 0.012 mg/l Zn, or 85X levels of Puget Sound. For the first 60 days after transfer, accumulation of Zn-65 ranged from 0.5 to 2 pCi/g(dry)/day; after 200 days the rate decreased to 0.25 pCi/g(dry)/day. Seasonal and annual differences in accumulation immediately after transfer were evident; accumulation rates generally decreased from spring to fall and from 1963 to 1965. Steady-state condition was not reached until after 500 days. Rate of loss was relatively constant at 0.55%/day. The effective and biological half-lives were estimated to be 125 and 255 days, respectively. Willapa Bay oysters concentrated Zn by a factor of 1.5×10^4, using a wet-dry ratio of 6.0 and Zn values of 515 mg/kg(dry) for oysters and 7.37 μg/l for seawater.

2074. Shaw, H.M., R.L. Saunders and H.C. Hall. 1975. Environmental salinity: its failure to influence growth of atlantic salmon (*Salmo salar*) parr. Jour. Fish. Res. Bd. Canada 32:1821-1824.

Instantaneous growth rates and food conversion efficiencies of salmon parr fed daily rations of 0 to 2.9% of dry body wt were similar at salinities of 0.1, 10 and 20^{o}/oo. Maintenance ration was slightly more in 20^{o}/oo than in 10^{o}/oo (salinity isomotic with blood) or 0.1^{o}/oo (freshwater).

2075. Shaw, T.L. and V.M. Brown. 1974. The toxicity of some forms of copper to rainbow trout. Water Research 8:377-382.

The LC-50 (24 hr) of total Cu, present as Cu^{2+} and $CuCO_3$, at pH 7.3-7.5, ranges from 0.07 to 0.25 mg Cu^{2+}/l at an alkalinity of 100 mg $CaCO_3$/l and from 1.15 to 2.08 mg Cu^{2+}/l at an alkalinity of 250 mg $CaCO_3$/l. Addition of neutralized NTA (nitrilotriacetic acid) to cupric copper produces an NTA-copper complex, which was tested for toxicity. In 8-day bioassays, 0.5 mg/l total copper (=0.03 mg/l free cupric ion, 0.47 mg Cu^{2+}/l as copper carbonate, and no Cu^{2+} as NTA-Cu complex) produced 50% mortality; 4.0 mg/l total copper (=0.01 mg/l free cupric ion, 0.16 mg Cu^{2+}/l as copper carbonate, and 3.83 mg Cu^{2+}/l as NTA-Cu complex) produced no deaths; 5.5 mg/l total copper (=0.03 mg/l free cupric ion, 0.47 mg Cu^{2+}/l as copper carbonate, 5.0 mg Cu^{2+}/l as NTA-Cu complex) produced 90% mortality. Authors concluded that the total concentration of soluble Cu and hence toxicity can be determined, except when highly toxic organocopper compounds are present.

2076. Shealy, M.H. and P.A. Sandifer. 1975. Effects of mercury on survival and development of the larval grass shrimp, Palaemonetes vulgaris. Marine Biology 33:7-16.

For grass shrimp, 56 ug Hg/l was toxic to all larvae within 24 hrs; below 5.6 ug Hg/l no lethal effect occurred within 48 hrs. LC-50's (48 hr) for fed and unfed larvae were 15.6 and 10.0 ug Hg/l, respectively. Latent effects of larval exposure for 48 hrs to sublethal mercury concentrations included: reduced survival to postlarval stage, delayed molting, extended development time, increased numbers of larval instars, and morphological deformities.

2077. Sherwood, M.J. 1975. Toxicity of chromium to fish. Ann. Rep. S. Calif. Coas. Water Res. Proj. El Segundo, Calif.:61-62.

For speckled sanddab Citharichthys stigmaeus, the LC-50 (96 hr) value for hexavalent chromium was 31.0 mg/l. The LC-50 (21 day) was 5.4 mg Cr^{+6}/l. Estimates for median effective concentrations (EC-50) for a feeding response for 4, 14 and 21 days were 15.0, 3.7 and 2.2 mg Cr^{+6}/l, respectively.

2078. Shin, E.-B. and P.A. Krenkel. 1976. Mercury uptake by fish and biomethylation mechanisms. Jour. Water Poll. Contr. Fed. 48(3):473-501.

Factors affecting methylmercury accumulation by teleosts included: chemical Hg species; type and number of microorganisms present; sorption characteristics of sediments; temperature; and chloride ion concentration. No discernible effect on uptake was evident by adding organics. Demethylation of methyl-Hg occurred in sediments with highest methylation rate at pH 7.

2079. Shulman, J., I.L. Brisbin and W. Knox. 1961. Effect of temperature, salinity, and food intake on the excretion of Zn^{65} in small marine fish. Biol. Bull. 121(2):378.

At 20 C and 35°/oo salinity, the biological half-life ($Tb\frac{1}{2}$) of Zn-65, administered via Venus meat soaked in Zn-$65Cl_2$, was 13 days for Menidia menidia as compared with 58 days for Fundulus heteroclitus; the metabolic rate of Fundulus is about 2X that of Menidia. For Fundulus, $Tb\frac{1}{2}$ was 75 days at 10 C and 35 days at 30 C, suggesting an inverse relationship of environmental temperature and excretion rate. A preliminary experiment showed that Fundulus's Tb½ was the same at 8 and 35°/oo salinity, indicating that gill salt excretion at high salinity does not materially increase Zn exchange.

Over a 17-day period, Zn-65 tagged specimens of Tautogolabrus adspersus at 20 C and 35°/oo salinity exhibited a Tb½ of 44 days at food levels varying from 153 to 58 cal/g fish/day. Tb½ of one specimen of T. adspersus which was starved for the 17-day period was 59 days.

2080. Shultz, C.D., D. Crear, J.E. Pearson, J.B. Rivers and J.W. Hylin. 1976. Total and organic mercury in Pacific blue marlin. Bull. Environ. Contamin. Toxicol. 15:230-234.

Nineteen marlin Makaira nigricons caught off the Kona side of Hawaii were analyzed for total mercury and organic mercury (methylmercury). Mean total mercury in mg/kg wet wt was 6.3 for liver, 2.0 for muscle, 0.5 for central nervous tissue, and 0.3 for gonads. Mean organic mercury in mg/kg wet wt was 0.4 for muscle, 0.2 for liver, 0.09 for central nervous tissue, and 0.07 for gonads. Authors state that the unusually high total to organic mercury ratio of 35:1 in liver may be a physiological mechanism to reduce Hg content by transforming organic mercury to its less toxic and more easily excretable inorganic form. Since all marlin were captured near an active volcano, and previous studies have shown greater biological levels of Hg near areas of high geothermal activity, it was possible that Hg in these marlin may be from natural causes.

2081. Shuster, C.N., Jr. and B.H. Pringle. 1968. Effects of trace metals on estuarine molluscs. Proc. First Mid-Atl. Indus. Waste Conf., 13-15 Nov. 1967: 285-304. Available from Dept. Civil Engineering, Univ. Delaware, Newark, Del.

American eastern oyster Crassostrea virginica, northern quahog Mercenaria mercenaria, and softshell clam Mya arenaria, collected from productive commercial shellfish beds from Maine through N. Carolina, contained the following metals contents in mg/kg wet wt of soft parts:

	oyster	quahaug	clam
Zn	180-4120	11-40	9-28
Cu	7-517	1-16	1.2-90
Fe	31-238	9-83	49-1710
Mn	0.14-15	0.7-29	0.1-29
Cd	0.10-7.8	0.10-0.73	0.10-0.90
Pb	0.10-2.30	0.10-7.5	0.10-10.2
Cr	0.04-3.40	0.19-5.8	0.10-5
Ni	0.08-1.80	0.10-2.4	0.10-2.3
Co	0.06-0.20	0.10-0.20	0.10-0.20

A rise in metal content of oysters during the past 35 years was noted.

Laboratory exposure studies of 20 weeks duration in flowing seawater showed at 20 weeks the following cumulative percentage mortalities, and total metal accumulations in mg/kg wet wt, during immersion in various concentrations of Cd, Cu, Co, Zn, or Pb:

	Test concentration (mg/l)	Oyster		Quahaug	
		% deaths	(residue)	% deaths	(residue)
Cd	0.1	32	(121)	3	(7)
	0.2	45	(96)	38	(15)
Cu	0.025	3	(630)	91	(2.2)
	0.05	6	(1060)	93	(3.6)
Co	0.05	5	(6)	0	(-)
	0.1	2	(11)	1	(-)
Zn	0.1	2	(1524)	0	(-)
	0.2	1	(2671)	0	(17)
Pb	0.2	1	(328)	0	(70)

Cd-exposed oysters showed inhibition of shell growth when compared to those exposed to Cu, Cr, or Zn. Quahaugs exposed to Zn exhibited a deep purple shell color.

2082. Sick, L.V. and H.L. Windom. 1975. Effects of environmental levels of mercury and cadmium on rates of metal uptake and growth physiology of selected genera of marine phytoplankton. In Howell, F.G., J.B. Gentry, M.H. Smith (eds.). Mineral cycling in southeastern ecosystems. U.S. Energy. Res. Dev. Admin.: 239-249. Avail. as CONF-740513 from NTIS, U.S. Dept. Comm. Springfield, VA 22161.

Rates of Hg-203 and Cd-109 uptake by algae were dependent on stable metal concentration, exposure time and algal species. Concentrations of Hg-203 uptake above 40 ug Hg^{2+}/l did not increase rates of uptake. Rates of Cd-109 uptake were 10 to 100X lower than Hg-203 and were directly proportional to metal added between 20 and 80 ug/l. Nitzischia exhibited higher uptake for both Hg and Cd than Carteria or Dunaliella and this may be due to its greater surface area. Concentrations of stable Hg^{2+} between 30 and 350 ug/l significantly depressed algal growth.

2083. Simmons, M.A. and A.W. Knight. 1975. Respiratory response of Neomysis intermedia (Crustacea: Mysidacea) to changes in salinity, temperature and season. Comp. Biochem. Physiol. 50A:181-193.

Neomysis respiration generally decreased as salinity increased from 1 to 70% seawater, with smaller mysids experiencing a greater change in respiration than larger ones. Respiratory response to temperature was weight dependent with larger mysids experiencing a greater change in respiration with temperature increase than smaller mysids. Seasonal temperature acclimation was apparent only at 6 C. Seasonal modification of respiration appeared to be related to changes in level of reproduction and type of available food.

2084. Sinley, J.R., J.P. Goettl, Jr. and P.H. Davies. 1974. The effects of zinc on rainbow trout (*Salmo gairdneri*) in hard and soft water. Bull. Environ. Contamin. Toxicol. 12:193-201.

LC-50 (96 hr) values for juvenile trout in hard water (330 mg/l as $CaCO_3$) and soft water (25 mg/l as $CaCO_3$) at 15 C were 7210 and 430 µg/l zinc as zinc sulphate, respectively. Bioassays with eyed eggs produced an LC-50 value of 2720 µg Zn/l in soft water, suggesting that this is one of the more resistant stages. The maximum allowable toxicant concentration (MATC) for trout after 21 months exposure in hard water fell between 640 µg Zn/l (6.4% mortality) and 320 µg Zn/l (no zinc-caused mortalities); growth rates and ovarian development were the same for all zinc concentrations tested. The MATC for trout after 21 months exposure in soft water ranged between 260 µg Zn/l (6.9% mortality), and 140 µg Zn/l (no deaths). Chronic toxicity of zinc to trout was dependent upon the life cycle stage at which exposure began. Fish not exposed to zinc as zygotes may be up to 4X more susceptible than those subjected initially to zinc as zygotes.

2085. Skei, J.M., M. Saunders and N.B. Price. 1976. Mercury in plankton from a polluted Norwegian fjord. Marine Poll. Bull. 7: 34-35.

Plankton of mixed composition were collected from Sorfjørden and Hardangerfjørden on west coast of Norway and analyzed for total Hg by atomic absorption. Five methods of decomposing the samples were tested, showing no significant variations in recovery of Hg. Levels ranged from 0.52 to 25.21 mg Hg/kg dry wt. Maximum values were found in southern part of Sorfjørden where three industrial companies are located, one of which discharged 3 kg Hg/day into fjord waters in 1972. Two samples contained larger portions of zooplankton than anticipated and showed lower Hg content than expected. This lower Hg concentration in zooplankton as compared to phytoplankton suggests a lack of food chain amplification in lower trophic levels.

2086. Skerfring, S., K. Hansson and J. Lindstem. 1970. Chromosome breakage in humans exposed to methyl mercury through fish consumption. Arch. Environ. Health 21:133-139.

Chromosome analysis was performed on cells from lymphocyte cultures from 9 subjects with increased levels of mercury in their red blood cells (21 to 370 mμg/g) and in 4 healthy controls (mercury levels 2 to 40X lower). The elevated mercury levels were likely to have originated from dietary fish containing 1 to 7 mg/kg wet wt of methylmercury. A statistically significant rank correlation was found between frequency of cells with chromosome breaks and mercury concentration.

2087. Skidmore, J.F. 1966. Resistance to zinc sulphate of zebrafish (*Brachydanio rerio*) embryos after removal or rupture of the outer egg membrane. Jour. Fish. Res. Bd. Canada 23:1037-1041.

Fifteen and 25-hr-old zebrafish embryos with the outer egg membrane ruptured survived longer in a solution of zinc sulphate (20 mg/l Zn) than embryos of the same ages with the membrane intact. Forty-two-hr embryos with the membrane completely removed survived in 4 concentrations of zinc sulphate (2.5, 5, 10, and 20 mg/l Zn) at least as long as 42-hr embryos with the membrane entire. The high resistance of zebrafish embryos to zinc was therefore not owing to protection by the membrane. On the contrary the presence of the membrane lowered resistance. This result was probably due to formation of opaque material enclosed by the outer egg membrane of zinc-poisoned, unruptured eggs. The action of this material in reducing survival is unknown.

2088. Slater, J.V. 1961. Comparative accumulation of radioactive zinc in young rainbow, cutthroat and brook trout. Copeia 1961:158-161.

Analysis of comparative accumulation rate of Zn-65 at a concentration of 0.1 μCi/ml in 7 to 8 month old trout showed greatest accumulation in brook trout *Salvelinus fontinalis*, at 37 x 10^{-3} counts/min/mg dry wt between 24 and 48 hrs of exposure. Uptake by cutthroat trout *Salmo clarki*, was 34 x 10^{-3} c/m/mg dry wt; for rainbow trout *Salmo gairdnerii*, this was 24 x 10^{-3} c/m/mg dry wt. In rainbow and cutthroat, gill filaments accumulated greatest amount of isotope, with operculum, tail and ventral body wall having respectively smaller accumulations. The ion uptake in cutthroat gill was almost twice that of rainbow gill.

2089. Small, L.F. and S.W. Fowler. 1973. Turnover and vertical transport of zinc by the euphausiid Meganyctiphanes norvegica in the Ligurian Sea. Marine Biology 18:284-290.

Participatory turnover time is defined as the time required to cycle an element in a system through a given material in that system. The participatory turnover time of ionic zinc by the adult M. norvegica population in the Ligurian Sea ranged between 498 and 1243 years, depending upon available food and considering food chain as the only route for zinc accumulation. A total impact turnover time was calculated as the sum of participatory turnover time for live individuals plus time required for dead euphausiids to lose 90% of their zinc to water. Carcasses lost zinc to water at a slower rate than either feces or molts, and so established the maximum loss time for all particulate excretion products. Nevertheless, total-impact turnover time for zinc did not differ significantly from the participatory turnover time. The net vertical transport of zinc by M. norvegica from sea surface to any specified depth can be calculated as sum of dissolved zinc excreted below the depth plus concentrations of zinc left in feces, molts, and carcasses after sinking to specified depth. Carcasses sink fastest and lose the smallest fraction of zinc during descent; fecal pellets sink slowest and lose the greatest fraction of their zinc; molts are intermediate. Feces represents the major route for delivering zinc to the Ligurian Sea bottom (2500 m), because concentration of the element in pellets is much higher (41-117 mg Zn/kg dry wt daily) than carcasses (up to 0.55) or molts (up to 1.35). Excretion of dissolved zinc into the water at the vertical migration depth of the living population during daylight hours was also inconsequential. Feces zinc represented over 80% of the total zinc transported to the sea floor if only marginal food supplies were available to the euphausiids, and over 90% if food was in sufficient supply. M. norvegica can effect a net transport of about 98% of its body zinc concentration below 500 m daily in conditions of sufficient food supply and assuming that no released products are eaten during descent. If the food supply in the Ligurian Sea is considered only marginal throughout the year, M. norvegica can still effect a daily net transport below 500 m of about 36% of its body concentration, and about 6% of its body concentration will reach 2500 m daily.

2090. Small, L.F., S. Keckes, and S.W. Fowler. 1974. Excretion of different forms of zinc by the prawn, Palaemon serratus (Pennant). Limnol. Oceanog. 19(5):789-793.

Fresh specimens of Palaemon serratus (300-1,600 mg wet wt), were collected from the upper Adriatic Sea and used to determine excretion rates of zinc in "zinc-free" water by anodic stripping polarographic techniques. Weight-specific excretion of total zinc varied reciprocally with body wt, in a log-log relationship. Weight-specific excretion of ionic-particulate zinc appeared greatest in short term (1-3 hr) experiments, while weight-specific excretion of complexed zinc appeared greatest in longer term (4-5 hr) experiments; however, authors concede the possibility that ionic-particulate zinc and dissolved organic compounds may be excreted separately with subsequent combination in water to yield zinc complex.

2091. Smith, A.L., R.H. Green and A. Lutz. 1975. Uptake of mercury by freshwater clams (family Unionidae). Jour. Fish. Res. Bd. Canada 32:1297-1303.

Mercury concentrations were measured in water, sediments and 3 species of clams from lakes with and without reported Hg contamination. Elevated mercury levels in clams were associated with elevated mercury levels in water and sediments. For example, Anodonta grandis from Clay Lake, Ontario, where Hg levels were comparatively high, i.e., 0.2 µg/l in water column and 0.10 mg Hg/kg in wet sediment, exhibited Hg levels, in mg/kg wet wt of 0.47 in mantle, 0.51 in gill, 0.83 in adductor muscle, 0.78 in liver, 0.62 in foot, 0.65 in visceral mass and 0.08 in decalcified shell, giving a whole clam value of 0.18. Clams from Minnedosa Lake, which had lower Hg levels of 0.01 µg/l in water column and 0.01 mg/kg in wet sediment exhibited lower Hg levels, in mg/kg wet wt, of 0.05 in foot, 0.07 in gill and 0.06 in liver, giving a whole clam value of 0.01.

Uncontaminated clams were exposed to 3 Hg compounds at 1, 10, 50, and 100 µg Hg/l for up to 3 weeks in the laboratory. Clams concentrated Hg in the order methylmercuric chloride > phenylmercuric acetate > mercuric chloride. Over a range of 1.0 to 100 µg Hg/l, Hg uptake rates were related to environmental levels; temperatures of 10 and 20 C produced essentially identical elimination rates. Distribution among organs depended on compound to which clams had been exposed. Of the 3 Hg species tested, only methylmercuric chloride was concentrated extensively in foot muscle. Transfer of methylmercuric chloride among organs apparently continued after exposure to compound had ended.

2092. Smith, B.P., E. Hejtmancik and B.J. Camp. 1976. Acute effects of cadmium on Ictalurus punctatus (catfish). Bull. Environ. Contamin. Toxicol. 15(3):271-277.

Catfish exposed to $\leq$800 µg Cd/l for 3 weeks showed concentration factors from 2 to 12 in liver, and 5 to 41 in kidney, with greatest magnification occurring at 50 µg Cd/l. Hematological constituents such as serum transaminase, serum triglycerides, albumin:globulin ratio, and serum Na and Mg were not significantly altered by this Cd treatment.

2093. Smith, D.C.W. 1956. The role of the endocrine organs in the salinity tolerance of trout. Mem. Soc. Endocrinol. 5:83-101.

In brown trout *Salmo trutta*, both thyroid activity and salinity tolerance peaked in the spring, but only salinity tolerance peaked in autumn; no correlation between the two was evident. Mature fish had a lower salinity tolerance than immature, but there was no difference in thyroid activity. Trout subjected to increasing salinity showed a fall in thyroid activity. Injection of thyroxine generally raised salinity tolerance; doses required were above the physiological level. Administration of thiourea and thiouracil reduced salinity tolerance. Posterior-pituitary extracts, testosterone propionate, chorionic gonadotrophin, thyrotrophin, ACTH and adrenocortical extracts had no significant effect on salinity tolerance; anterior-pituitary extracts and growth hormone raised salinity tolerance; threshold for growth hormone is below 30 µg/10 g fish/week—probably a physiological dose.

2094. Smith, D.H. 1967. R factors mediate resistance to mercury, nickel, and cobalt. Science 156:1114-1116.

Clinical isolates and laboratory stocks of *Escherichia coli* and *Salmonella* bacteria were studied for resistance to Al, Cd, Cr, Co, Cu, Pb, Hg, Ni, Ag and Tl. Eleven clinical isolates carrying R factors were resistant to Hg. Resistance was mediated by a previously undefined R-factor gene, phenotypically expressed within 2 to 4 minutes after entry into sensitive bacteria. Fourteen strains, 12 infected with R factors, were resistant to Co and Ni, but these resistances were mediated by R-factor genes in only two strains; separate R-factor genes mediated resistances to Ni and Co. Results indicate that genetic composition of R factors is greater than originally defined.

2095. Smith, E.J. and J.L. Sykora. 1976. Early developmental effects of lime-neutralized iron hydroxide suspensions on brook trout and coho salmon. Trans. Amer. Fish. Soc. 105:308-312.

Effects of lime-neutralized iron hydroxide suspensions on eggs and alevins of brook trout *Salvelinus fontinalis*, and coho salmon *Oncorhynchus kisutch*, were interpreted from data on hatchability, survival, and growth in 5 test concentrations from 0.75 to 10.5 mg Fe/l, and controls. Growth of 90 day-old coho salmon alevins was reduced in water containing 1.27 mg Fe/l of lime-neutralized suspended iron, whereas hatchability was unaffected in highest concentration tested of 10.5 mg Fe/l. Concentration of 10.5 mg Fe/l had no measurable effect on hatchability, survival and growth of brook trout alevins. Safe upper limit of lime-neutralized suspended iron for coho salmon alevins lies between 0.97 and 1.27 mg Fe/l.

2096. Smith, M.W. 1935. The use of copper sulphate for eradicating the predatory fish population of a lake. Trans. Amer. Fish. Soc. 65:101-114.

Copper sulphate was added to a Nova Scotia lake in August, 1934, in sufficient quantity to yield a concentration of 3.06 mg/l. Phytoplankton were decimated and continued to be scarce for almost a year. Rooted, submerged, and emergent vegetation appeared little affected. Zooplanktonic forms were drastically reduced in number. All clams and snails were killed; insect abundance was reduced. Fish mortalities were high, with most dead individuals found in shallow water. Author suggests that death in fish was due to precipitation of mucus on gills, leading to suffocation.

2097. Smith, P.G. 1969. The ionic relations of *Artemia salina* (L.). II. Fluxes of sodium, chloride, and water. Jour. Exp. Biol. 51:739-757.

Effects of different external media (including lithium, choline, and benzenesulphonate) on sodium and chloride efflux in brine shrimp *Artemia salina*, were observed in animals acclimatized to seawater. In seawater, both sodium and chloride fluxes across epithelium are approximately 7 x 10^{-15} M/cm^2/sec (or 1.6 x 10^{-10} and 2.5 x 10^{-10} mg/cm^2/sec, respectively). Sodium efflux drops markedly in sodium-free media, and chloride efflux falls in chloride-free media; the two effects are independent and not due to changes in external osmolarity. Decreases in Na efflux can be explained by changes in electrical potential difference and diffusional permeability; exchange diffusion of sodium does not occur.

Approximately 70% of the chloride efflux (22 x 10^{-13} M/sec) is due to exchange diffusion (12 x 10^{-13} M/sec), while the remainder is primarily due to active transport (9.0 x 10^{-13} M/sec). The plot of ion efflux against external concentration, fitted by a Michaelis-Menten equation, does not constitute evidence for presence of exchange diffusion; graphs of similar shape can be obtained if flux is simply diffusional. Drinking rate, determined from rate of uptake of I-131-polyvinylpyrrolidone is 2.0% body wt/hr, or 20 ml/kg/hr. Diffusional influx of water is 24 x 10^{-13} l/sec.

2098. Solbé, J.F. de L.G. and V.A. Cooper. 1976. Studies on the toxicity of copper sulphate to stone loach *Noemacheilus barbatulus* (L.) in hard water. Water Research 10:523-527.

The LC-50 (63 day) value of copper sulphate to *N. barbatulus* was about 0.25 mg Cu/l in water of total hardness 249 mg/l as $CaCO_3$;

larger fish survived longer. At concentrations >0.29 mg Cu/l, fish took shelter less frequently during daylight hours. *Noemacheilus* surviving 0.12 mg Cu/l for 64 days depurated Cu when placed in clean water for 7 days: gill, muscle, eye and vertebrae lost significant amounts of Cu during this period. Tissue levels of Cu, in mg/kg dry wt, in fish killed by 0.76 mg Cu/l were 18 in eye, 164 in gill, 8 in muscle, 7 in vertebrae and 115 in liver, compared to control levels of 19, 26, 5, 3 and 53, respectively.

2099. Sorensen, E.M.B. 1976. Toxicity and accumulation of arsenic in green sunfish, *Lepomis cyanellus*, exposed to arsenate in water. Bull. Environ. Contamin. Toxicol. 15:756-761.

Time for 50% death (LT-50) for green sunfish *L. cyanellus* immersed in 100, 500 or 1000 mg/l arsenic as sodium arsenate was 46, 17 and 12 hrs, respectively. When cumulative percent mortality was observed against 3 size classes, no variation was observed in 500 and 1000 mg/l As levels. The smallest fish exposed to 100 mg/l As died at a more rapid rate than the other 2 size classes. LT-50 values for small, intermediate and large fish exposed to 100 mg/l As are 39, 55 and 73 hr, respectively. LC-50 values for 12, 18, 24 and 48 hr were 1000, 350, 175 and 150 mg/l As, respectively. Arsenic accumulation increased with increasing As exposure levels. Mean As accumulation was 33, 541, and 581 mg/kg for As exposure levels of 100, 500 and 1000 mg/l, respectively. No correlation was observed with As accumulation and fish total length, wet wt, dry wt, or condition.

2100. Spaargaren, D.H. 1972. Osmoregulation in the prawns *Palaemon serratus* and *Lysmata seticaudata* from the Bay of Naples. Netherlands Jour. of Sea Res. 5:416-436.

Measurement of blood osmotic concentrations reveal *P. serratus* to be strongly regulating and *L. seticaudata* to have a high degree of osmoconformity. Both species were equally capable of regulating the electrolyte concentrations in tissues; non-electrolyte concentrations in cells followed changes in blood osmolarity. A strong influence of temperature on osmotic concentrations of blood and homogenate of *P. serratus* is evident; in blood this is due to changes in electrolyte concentration; in homogenate by alteration of non-electrolyte concentration. In *L. seticaudata*, total osmotic concentrations are practically independent of temperature. Urine excretion does not play an important role in water and salt regulation of either species. Gross extra-renal efflux of electrolytes is greatest at normal salinities for these species. Permeability is actively controlled, with decreases at supranormal salinities. For both prawn species transfer to lower salinities results within a few hours in decrease of blood concentrations. During this osmotic adaptation a strong increase of blood non-electrolytes occurs within 10 minutes. These are probably liberated from the tissues. Results are compared with osmoregulatory patterns and migrational behavior of two shrimps in the North Sea and the Wadden Sea, Crangon crangon and C. allmanni, which have been indicated incapable of surviving high salinities and temperatures to which Palaemon serratus and Lysmata seticaudata are exposed in the Bay of Naples.

2101. Spangler, W.J., J.L. Spigarelli, J.M. Rose, R.S. Flippin and H.H. Miller. 1973. Degradation of methylmercury by bacteria isolated from environmental samples. Appl. Microb. 25:488-493.

Of 207 bacterial cultures isolated from fish and sediment from Lake St. Clair, Michigan, 30 isolates were positive for aerobic demethylation without adaptation to methylmercury. Of the 30 positive isolates, 22 were facultative anaerobes, and 21 of these were capable of anaerobic demethylation. Two of the isolates were gram-positive cocci, two gram-positive rods, and the remainder gram-negative rods with characteristics typical of Pseudomonas. Although methylmercury degradation was complete in most cases, some inorganic Hg formed was not volatilized and is presumed bound to cells. All positive isolates were tolerant to at least 0.5 μg of methylmercury per ml with increasing volatilization at increasing concentration until threshold value is reached. Results indicate that demethylating species are prevalent in the environment and may be important in suppressing methylmercury content of sediments.

2102. Spehar, R.L. 1976. Cadmium and zinc toxicity to flagfish, Jordanella floridae. Jour. Fish. Res. Bd. Canada 33:1939-1945.

The LC-50 (96 hr) values for Cd to juvenile flagfish was 2,500 μg/l; for Zn this was 1,500 μg/l. In chronic tests, reproduction was the most sensitive indicator of Cd toxicity and was inhibited at 8.1 μg/l. Fish exposed to 1.7 μg/l and above accumulated significantly greater amounts of Cd than controls. In Zn tests, survival of larvae (not exposed as embryos) and growth of females were the most sensitive measure of Zn toxicity; these were reduced at respective concentrations of 85 and 51 μg/l. Significant uptake of Zn occurred in fish exposed to 47 μg/l and above. The lowest Cd and Zn concentrations causing adverse effects to flagfish were similar to those affecting other freshwater fish species.

2103. Spinelli, J. and C. Mahnken. 1976. Effect of diets containing dogfish (Squalus acanthias) meal on the mercury content and growth of pen-reared coho salmon (*Oncorhynchus kisutch*). Jour. Fish. Res. Bd. Canada 33:1771-1778.

Use of dogfish meal containing 1.4 to 2.3 mg total Hg/kg, including 1.1 to 1.9 mg Hg/kg as methyl-Hg, as a complete replacement for low Hg fish rations led to salmon muscle Hg levels $\geq$0.5 mg/kg, the U.S. FDA tolerance level, in 240 days. Muscle Hg levels did not rise above 0.5 mg/kg when dogfish meal replaced <50% of fish meal portion. Chelating agents in dehydrated orange peel or polygalacturonic acid-cellulose complexes did not prevent deposition in either muscle or liver tissues of salmon.

2104. Stebbing, A.R.D. 1976. The effects of low metal levels on a clonal hydroid. Jour. Mar. Biol. Assn. U.K. 56:977-994.

Concentrations, in ug/l, which depressed growth rate of the colonial marine hydroid *Campanularia flexuosa* over an 11 day period were: 1.6 to 1.7 for Hg^{2+}; 10 to 13 for Cu^{2+}; and 110 to 280 for Cd^{2+}. Growth stimulation was observed at 1 ug/l for Cu between days 7 and 11; 1 ug/l of Hg produced a similar effect between days 3 and 7.

2105. Stenner, R.D. and G. Nickless. 1974. Absorption of cadmium, copper and zinc by dog whelks in the Bristol Channel. Nature 247:198-199.

Mean metal levels in mg/kg dry flesh of whelks *N. lapillus*, transplanted from Beer, Dorset, to Bristol Channel rose from 36 to 211 for Cd, 70 to 170 for Cu and 345 to 2530 for Zn in 5 months. Levels of local specimens in mg/kg dry flesh were 780 for Cd, 905 for Cu and 2900 for Zn. Limpets *Patella* sp. similarly transplanted showed a rise of mean metal concentrations in mg/kg dry flesh of 11 to 220 for Cd, 7 to 30 for Cu, and 91 to 340 for Zn in 8 months.

2106. Stenner, R.D. and G. Nickless. 1974. Distribution of some heavy metals in organisms in Hardangerfjord and Skjerstadfjord, Norway. Water, Air, and Soil Poll. 3:279-291.

Near Adda, West Norway, metal-bearing waters enter the Sorfjord, a tributary of the Hardangerfjord. Unusually high concentrations of Cd, Pb, and Zn are present in marine life over considerable length of the fjord. Marine life near Adda also contained concentrations of Hg higher than normal. At Fauske, North Norway, marine organisms contain high concentrations of Cu, but this contamination is confined to a small area of the Skjerstadfjord system.

Highest metal concentrations for all organisms collected over the entire region, in mg/kg dry wt, were:

	Cd	Cu	Zn	Pb	Hg	Ni	Mn
Algae	20	170	2370	1200	1.2	--	--
Crustacea	8.8	94	275	31	--	--	--
Echinoderms	18	18	1500	460	--	--	--
Molluscs	140	190	2900	3100	0.6	--	--
Fish flesh	0.7	4	45	14	0.6	--	--
Sediments (mg/kg)	1.5	18	64	66	--	--	--
Water (ug/l)	85	77	3560	27	--	5.6	16.9

2107. Stenner, R.D. and G. Nickless. 1975. Heavy metals in organisms of the Atlantic coast of S.W. Spain and Portugal. Marine Poll. Bull. 6:89-92.

Very high concentrations of copper, lead, zinc, and to a lesser extent mercury, are present in the estuary of the Rio Tinto in Southwest Spain. At the mouth of the estuary, concentrations fall very sharply towards natural levels of these metals in organisms living in this part of the Atlantic.

Highest values observed in mg metal/kg dry wt in flesh from edible molluscs and crustaceans were: 32 for Cd, 205 for Cu, 516 for Pb, 280 for Zn, and 0.03 for Hg. For fish flesh this was 3.2 for Cd, 8 for Cu, 7 for Pb, 132 for Zn, and 0.79 for Hg. Highest values recorded for cadmium in mg/kg dry wt were 7.4 for algae, 12.1 for barnacles, 16.0 for gastropods, 4.1 in sediments, and 6 (ng/l) for water. For Cu, highest values recorded were 26 mg/kg dry wt in algae (except *Zostera* which was 1350), 26 for molluscs, up to 600 in barnacles, up to 1400 in sediments, and up to 107 (ng/l) in water. Highest Zn values were 320 mg/kg dry wt for molluscs, 145 for algae (exception *Zostera* 1480), up to 3300 in barnacles, 3100 in sediments, and up to 525 (ng/l) in water. For Pb, highest values determined were 22 for algae (except *Zostera* which was 1800 mg/kg dry wt), up to 1600 in sediments, and up to 38 (ng/l) in water. Highest Ni and Mn levels in water (ng/l) were 10.8 and 108, respectively.

2108. Stephenson, R.R. and D. Taylor. 1975. The influence of EDTA on the mortality and burrowing activity of the clam (*Venerupis decussata*) exposed to sublethal concentrations of copper. Bull. Environ. Contamin. Toxicol. 14(3):304-308.

Clams were exposed to copper concentrations (in mg/l) of 0.1 Cu, 0.01 Cu, 0.1 Cu plus 1.0 mg/l EDTA, and 0.01 Cu plus 1.0 mg/l EDTA for 75 days; controls were exposed to seawater or seawater plus 1.0

mg/l EDTA. The EDTA plus Cu group, and the controls exhibited about 2% death. All Venerupis exposed to 0.1 mg/l Cu died within 50 days; the 0.01 mg/l Cu group had deaths between the 30th and 91st days only. Control populations and those exposed to EDTA showed no inhibition of burrowing; but those exposed to copper alone showed a significant decline. Normal burrowing was regained within 30 days when exposure to 0.01 mg/l Cu ceased.

2109. Stevenson, R.A. and S.L. Ufret. 1966. Iron, manganese and nickel in skeletons and food of the sea urchins Tripneustes esculentus and Echinometra lucunter. Limnol. Oceanogr. 11(1): 11-17.

Levels of Fe, Ni, and Mn in skeletons of 2 species of sea urchins from two collection sites were determined. Levels in mg/kg dry wt of T. esculentus and E. lucunter from Punta Higuero, Puerto Rico, were 81 and 38 for Fe, 14 and 21 for Mn, and 35 and 52 for Ni, respectively. In urchins from La Parguera, PR, levels were 53 and 35 for Fe, 13 and 20 for Mn and 35 and 49 for Ni. For the marine angiosperm Thalassia testudinum, the main food source of T. esculentus at La Parguera, levels were 250, 49, and 20 mg/kg dry wt for Fe, Mn and Ni, respectively. Padina gymnospora, the principle forage alga of T. esculentus at Punta Higuero, contained 4100, 99 and 27 mg/kg dry wt of Fe, Mn, and Ni, respectively, but these higher levels were not reflected in urchin.

2110. Stewart, J. and M. Schulz-Baldes. 1976. Long term lead accumulation in abalone (Haliotis spp.) fed on lead-treated brown algae (Egregia laevigata). Marine Biology 36:19-24.

The amount of lead accumulated in body of a grazing mollusc by transfer from its algal food was assessed in laboratory experiments and compared with amounts found in naturally occurring molluscs and seaweed. Near La Jolla, California, where concentration of Pb in seawater is probably less than 0.08 μg/l and most of the naturally occurring Egregia laevigata contains less than 0.4 mg Pb/kg wet wt, the total body masses without shells of juvenile abalone Haliotis rufescens fed on this seaweed for 3 to 6 months showed similar concentrations. When E. laevigata is placed for 1 to 6 days in seawater with a Pb concentration of 0.1 or 1.0 mg/l, both seaweed and abalone accumulate proportionately larger amounts of Pb. After 6 months, young abalone fed on E. laevigata pretreated with 1.0 mg Pb/l accumulated up to 21 mg Pb/kg wet wt. This amount of Pb had no apparent consequences on growth or activity of molluscs. Analyses of 6 different organs from adult abalone showed that Pb was selectively concentrated in digestive gland. In the foot (muscle tissue), which is the part normally consumed by humans, only negligible amounts were found.

2111. Stickle, W.B. and T.W. Howey. 1975. Effects of tidal fluctuations of salinity on hemolymph composition of the southern oyster drill, Thais laemastoma. Marine Biology 33:309-322.

Amplitude of hemolymph osmolality and ion fluctuation in oyster drills during laboratory simulated tidal fluctuations of salinity (30-10-30°/oo S, 20-10-20°/oo S, or 10-5-10°/oo S) was directly related to the amplitude of ambient salinity fluctuation and inversely related to rate of fluctuation. Rate of hemolymph osmolality and ion change was directly related to rate of ambient salinity change. Dilution of seawater with simulated Mississippi River water instead of deionized water resulted in a reduced amplitude of fluctuation of hemolymph osmolality and ion concentration. Most hemolymph osmolality fluctuation was due to solute movement; less than 22% was due to shifts in body water. Hemolymph, Na^+ and Cl^- levels changed similarly throughout all experiments except the 10-5-10°/oo S-simulated river-water experiment in which Cl^- changed much less than Na. Hemolymph ninhydrin-positive substance (NPS) levels cycled inversely with ambient salinity during 30-10-30°/oo and 20-10-20°/oo S diurnal and 30-10-30°/oo semidiurnal experiments, but did not change during 10-5-10°/oo S deionized water or simulated river-water experiment. Snails fed for most of the 2-week 20-10-20°/oo S diurnal cycle fluctuation experiment and, with no deaths recorded. Drills were hyperosmotic to ambient water at all but two isosmotic sampling periods. Hemolymph NPS levels tended to be higher during low-salinity slack water than high-salinity slack water. Even small fluctuations of ambient salinity result in fluctuations of hemolymph osmolality and ionic composition which may affect rate functions within the zone of capacity adaptation.

2112. Stickney, R.R., H.L. Windom, D.B. White and F.E. Taylor. 1975. Heavy-metal concentrations in selected Georgia estuarine organisms with comparative food-habit data. In Howell, F.G., J.B. Gentry and M.H. Smith (eds.). Mineral Cycling in Southeastern Ecosystems. U.S. Energy Res. Dev. Admin.: 257-267. Available as CONF-740513 from NTIS, U.S. Dept. Comm., Springfield, VA 22161.

Mean metal levels in mg/kg dry muscle of 11 species of estuarine fishes ranged from 0.02 to 0.22 for Cd, 0.9 to 5.2 for Cu, 0.01 to 0.16 for Pb, 0.10 to 2.74 for Hg and 21 to 51 for Zn. Mean metal levels in mg/kg dry tissue of various parts of 12 species of crustacea which serve as food organisms, ranged from 0.01 to 0.40 for Cd, 13 to 74 for Cu, 0.03 to 0.94 for Pb, 0.06 to 1.57 for Hg and 55 to

290 for Zn. No positive correlation between metal levels and food habits of fish existed, although high Hg levels in oyster toad fish *Opsanus tau* appeared to be associated with elevated Hg levels in crabs, its major food source. Cu and Zn were commonly higher in invertebrates than fish predators. Authors conclude that trace metal contents in organisms of different trophic levels depend more on physiological processes within each organism than on metal content of food.

2113. Stiefel, R.C. 1974. Mercury as a factor in the fisheries environment. Ohio Dept. Natur. Res., Div. of Wildlife. 45 pp.

Analyses of total mercury concentration in 40 species of freshwater fish from 195 locations throughout Ohio indicate that while there is some mercury in nearly every fish tested, there are only a few species of fishes from a limited number of locations throughout the state that contain excessive concentrations of mercury. Only 128 of the 1537 samples analyzed contained mercury in concentrations above 0.5 mg/kg; and fully one-third of these samples were collected from one river basin and at one other location in the state. The species of fishes that contain high mercury concentrations and the highest Hg level found in them, are: longnose gar *Lepisosteus osseus* (1.10 mg/kg Hg); northern pike *Esox lucius* (0.98 mg/kg); channel catfish *Ictalurus punctatus* (0.93 mg/kg); flathead catfish *Pylodictis olivaris* (1.04 mg/kg); white bass *Morone chrysops* (1.52 mg/kg); rockbass *Ambloplites rupastris* (1.33 mg/kg); smallmouth bass *Micropterus dolomieut* (1.00 mg/kg); spotted bass *M. punctulatus* (1.19 mg/kg); largemouth bass *M. salmoides* (1.00 mg/kg); and walleye *Stizostedion vitreum* (0.59 mg/kg). The majority of these were greater than 25 cm in length and very high in the food chain, with diets including the smaller species of fish. Based on these results, it is concluded that mercury contamination is not a serious problem in the fisheries environment in the State of Ohio.

2114. Stiff, M.J. 1971. Copper/bicarbonate equilibria in solutions of bicarbonate ion at concentrations similar to those found in natural water. Water Research 5:171-176.

The equilibrium constant for reaction between cupric and bicarbonate ions resulting in formation of the soluble complex species $CuCO_3$, was determined by means of a cupric ion selective electrode. If cupric ion were the toxic form of Cu, and copper carbonate complex was relatively non-toxic, this could account for differences observed in copper toxicity to fish in hard and soft waters. Differences in toxicity would not be related to water hardness *per se* but to differences in alkalinity which it accompanies.

2115. Stokes, P.M., T.C. Hutchinson and K. Krauter. 1973. Heavy-metal tolerance in algae isolated from contaminated lakes near Sudbury, Ontario. Canad. Jour. Bot. 51:2155-2168.

Algal isolates of Chlorella and Scenedesmus from two lakes in the smelting region of Sudbury, Ontario, were the test species. Copper and nickel content, in mg/l, for the two lakes were Cu 0.52-0.74, and Ni 2.7-3.2 in Baby Lake and Cu 0.10-0.13 and Ni 2.5 in Boucher Lake. Growth, as determined by cell numbers was tested under control conditions in defined media with nutrient conditions, pH, copper, and nickel concentrations used as variables.

Lake Scenedesmus were especially metal tolerant. Cell division was active at 0.4 mg Cu/l whereas the laboratory strain (control) was killed at 0.1 mg Cu/l. Tolerance to Ni was more pronounced with continued growth at 1.5 mg Ni/l compared to 0.25 mg Ni/l for laboratory strains. Lake Chlorella was less tolerant than lake Scenedesmus to Cu, ceasing cell division at 0.15 mg Cu/l. Laboratory Chlorella died at concentrations above 0.04 mg Cu/l. Pattern of response also differed between lake isolates and lab strains in that the latter showed a threshold effect, with inhibition and death above a certain critical metal level, but little inhibition below this level. The lake strains showed a gradual reduction in growth with increasing metal level. In cultures that very high levels of Cu prevented cell division, cells of lake strains were comparatively large and contents distorted, but these were able to resume normal appearance and division in media containing less Cu.

2116. Strik, J.J.T.W.A., H.H. de Iongh, J.W.A. van Rijn van Alkemade and T.P. Wuite. 1975. Toxicity of chromium (VI) in fish, with special reference to organoweights, liver and plasma enzyme activities, blood parameters and histological alterations. In Koeman, J.H. and J.J.T.W.A. Strik (eds.). Sublethal effects of toxic chemicals on aquatic animals. Elsevier Sci. Publ. Co., Amsterdam: 31-41.

Rainbow trout Salmo gairdnerii, exposed to 10 mg/l Cr^{+6} for 14-22 days, showed decreased activity and food intake after 5 days, with 25% mortality by the 15th day. Intestines of treated trout contained swollen blood vessels. Chromium-treated trout when compared to controls exhibited increased hematocrit, increased hemoglobin, decreased blood Na^+ content, a higher incidence of swollen salt cells and slime cells, gill damage, and severe necrosis of kidney tubules.

Roach Rutilus rutilus (teleost) were exposed for 32 days to 0, 0.1, 1.0 or 10 mg/l of Cr^{+6}. Roach in 10 mg/l group showed decreased activity and food intake. There was no difference among groups in weights of liver, kidney and gonad, or in various blood parameters (hematocrit, hemoglobin, RBC, WBC) or various liver homogenate enzymes (glutamate-pyruvate-transaminase and glucose-6-phosphate-dehydrogenase). Glutamate-oxaloacetate-transaminase activity in liver homogenate of roach exposed to 10 mg/l decreased when compared to controls. Blood glucose content of roach exposed to 10 mg Cr^{+6}/l differed ($P<0.005$) from 1 mg Cr/l group and ($P<0.10$) the 0.1 mg Cr/l group, but not from controls. Acid phosphatase activity in blood plasma was the same in all four groups.

2117. Strohal, P., D. Huljev, S. Lulić and M. Picer. 1975. Antimony in the coastal marine environment, North Adriatic. Estuarine and Coastal Marine Science 3:119-123.

Levels of stable antimony in North Adriatic coastal waters were determined by neutron activation. The following concentrations were obtained: 0.31 ug Sb/dm^3 in the case of 0.45 um filtered seawater and 45 ug Sb/dm^3 for non-filtered seawater, respectively. Concentrations of stable antimony in 18 species of marine organisms including representative species of algae, molluscs, crustacea, and fish, in mg Sb/kg wet wt, ranged between 6.7×10^{-8} and 9.2×10^{-7}. Values for sediments were somewhat higher (2.0×10^{-5}). Laboratory tracer experiments on sorption of Sb-125 by limestone, dolomite, quartz, and marine sediments were also conducted.

2118. Stubbs, G., A. More, J.R. Nicholls, O.L. Brady, J. Eyre, F.S. Wright and J.H. Orton. 1924. An account of investigations into the cause or causes of the unusual mortality among oysters in English oyster beds during 1920 and 1921. Part II. Minist. Agric. Fish. Fishery Invest. Ser II, Vol. VI, No. 4. 69 pp.

Oyster deaths due to direct poisoning (primarily TNT, but also arsenic and other compounds), parasites, disease, predators, and other causes were investigated.

Arsenious oxide (As_4O_6) content of pooled samples of oysters from Whitstable in 1920 ranged from 0.44 to 1.87 mg/kg wet wt. Wet digestion methods yielded higher As values than ashing. Silt and other materials adhering to the outside of oyster shells contained 3 mg/kg arsenious oxide. No arsenic was detected in scrapings from the inside of oyster shells. Source of arsenic was unknown; however, arsenic compounds were manufactured in the London area and "it is quite possible that a ship with a large cargo of white arsenic, which I believe is largely imported into this country, was sunk in the Thames Estuary during the war and is now breaking up."

Oysters (n=50 per sample) from Whitstable collected in 1921 examined by the wet combustion process contained 3.5-3.7 mg As (as As_4O_6) kg wet wt; this is 2.5X the maximum limit suggested by the Royal Commission on Arsenical Poisoning for arsenic in food substances generally. On the other hand, more than 3 to 12 dozen oysters would have to be consumed to exceed a (then) medicinal dose of arsenic.

Content of As, Zn, Pb, Cu, and Sn in healthy and diseased oysters was determined. In general, As content was low or absent in both groups, and this may be associated with the comparatively high copper content of healthy oysters (up to 970 mg Cu/kg wet wt). Values for Zn and Sn were as high as 1360 and 40 mg/kg wet wt, respectively; Pb was never detectable in any samples. One sample of 53 oysters was dark blue in color; on analysis these showed abnormally high levels of Cu (3300 mg/kg wet wt), Zn (2100), and Sn (220)—or about 0.5% Zn and Cu.

2119. Stutzenberger, F.J. and E.O. Bennet. 1965. Sensitivity of mixed populations of *Staphylococcus aureus* and *Escherichia coli* to mercurials. Applied Microb. 13:570-574.

S. aureus exhibited higher resistance to merbromin and mercuric chloride in presence of *E. coli*. This protective effect was attributed to production of extracellular glutathione and hydrogen sulfide and to an unequal distribution of inhibitor between the two species. *S. aureus* did not significantly influence the resistance of *E. coli* to mercurials.

2120. Styron, C.E., T.M. Hagan, D.R. Campbell, J. Harvin, N.K. Whittenburg, G.A. Baughman, M.E. Bransford, W.H. Saunders, D.C. Williams, C. Woodle, N.K. Dixon and C.R. McNeill. 1976. Effects of temperature and salinity on growth and uptake of Zn-65 and Cs-137 for six marine algae. Jour. Mar. Biol. Assn. U.K. 56:13-20.

Population growth and concentration factors for Zn-65 and Cs-137 have been measured for *Achnanthes brevipes*, *Carteria* sp., *Chlamydomonas* sp., *Dunaliella salina*, *Nannochloris atomus*, and *Phaeodactylum tricornutum* subjected to factorial combinations of 8 temperatures (6-40 C) and 10 salinities (3.5-44.0^{o}/oo). Regression coefficients were calculated for polynomial models describing response surfaces for growth and radionuclide concentration. Salinity was more important than temperature in describing population growth for *Carteria*, *Dunaliella*, *Nannochloris* and *Phaeodactylum*. No independent variable was consistently of primary importance in describing Cs-137 concentration factors, while temperature accounted for more variation in Zn-65 concentration factors than salinity or population growth in all algae except Dunaliella. Concentration factors for Zn-65 were uniformly higher than Cs-137 concentration factors.

2121. Sugiura, K., S. Sato, M. Goto and Y. Kurihara. 1976. Toxicity assessment using an aquatic microcosm. Chemosphere 5(2):113-118.

Changes in freshwater community structure, productivity, and respiration were analyzed following addition of Cu ions. The aquatic microcosm consisted of 5 or more species of bacteria; the ciliate, Cyclidium; rotifers, Philodina and Lepadella; a species of aquatic oligochaete; green algae, Chlorella and Scenedesmus; and blue green algae. When Cu was added at beginning of cultivation, organism density differed from controls at 0.3 mg/l. When added at a stationary stage (25th day) effects on organism density were observed at 0.9 mg/l. Differences in concentration at which decline in densities occur may be due to increased output of bacterial metabolities, which form complexes with Cu ions. These complexes inhibit growth and accelerate mortality of Cyclidium and Chlorella to a greater extent than Cu ions alone. Gross production, total respiration and net production measurements show that even when density of organisms in the system are the same as controls, toxicity can be assessed.

2122. Sullivan, G. and A.L. Buikema, Jr. 1972. The effect of hardness on the toxicity of zinc sulfate to the rotifer Philodina sp. (Bdelloidea, Bdelloida, Philodinidae). The ASB Bull. 19(2):104.

Toxicity of zinc sulfate to Philodina sp. in water with a total hardness of 280 mg/l produced an LC-50 (24 h) >100 mg/l at pH 6.9 and 23 C. By contrast, toxicity of zinc sulfate in deionized water was considerably greater; the LC-50 (24 h) being <1 mg/l at pH 6.5 and 23 C.

2123. Sullivan, G.W., A.L. Buikema and J. Cairns. 1973. Acute bioassays for the assessment of heavy metal pollution using the freshwater littoral rotifer, Philodina sp. Virginia Jour. Sci. 24:120. (Abstract)

LC-50 (96 hr) values at 20 C for Philodina were in mg/l: 3.1 for $K_2Cr_2O_7$, 0.1 for $CdSO_4$, 0.4 for $CuSO_4$, 0.7 for $HgCl_2$, 1.3 for $ZnSO_4$, and 40.8 for $PbCl_2$.

2124. Summers, A.O. and E. Lewis. 1973. Volatilization of mercuric chloride by mercury-resistant plasmid-bearing strains of *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*. Jour. Bact. 113:1070-1072.

Strains of *E. coli*, *S. aureus* and *P. aeruginosa* were examined for ability to volatilize Hg-203 added as $HgCl_2$, and to convert added Hg-$203Cl_2$ to a chloroform soluble form. Strains carrying independently isolated plasmids with genes determining resistance to Hg will convert $HgCl_2$ to a volatile form of Hg which is soluble in organic solvents. This form of Hg is very likely metallic Hg, rather than an alkyl mercury compound.

2125. Summers, A.O. and S. Silver. 1972. Mercury resistance in a plasmid-bearing strain of *Escherichia coli*. J. Bacteriol. 112:1228-1236.

A strain of *E. coli* carrying genes determining mercury resistance on a naturally occurring resistance transfer factor converts 95% of 10^{-5}M Hg^{2+} (chloride) to metallic mercury at a rate of 4 to 5 nmoles of Hg^{2+} per min per 10^8 cells. The metallic mercury is rapidly eliminated from the culture medium as mercury vapor. Volatilizing activity is temperature dependent, has a heat sensitivity characteristic of enzymatic catalysis, and is inducible by mercuric chloride. Ag^+ and Au^{3+} are markedly inhibitory of mercury volatilization.

2126. Sumner, A.K., J.G. Saha and Y.W. Lee. 1972. Mercury residues in fish from Saskatchewan waters with and without known sources of pollution - 1970. Pesticides Monit. Jour. 6:122-126.

Mercury concentrations in dorsal muscle from goldeye, longnose sucker, pike, sauger, and perch taken from the Saskatchewan River system ranged from 0.18 to 8.88 mg/kg wet wt. This river receives industrial and municipal wastes containing Hg. Mercury levels were higher (0.18 to 8.88 mg/kg wet wt) in fish caught downstream from a chlor-alkali plant, with highest average Hg concentration found in goldeye (2.05 mg/kg wet wt) and pike (4.80 mg/kg wet wt) collected several kilometers downstream from the chlor-alkali plant. Fish from an upstream site but contaminated with municipal or other types of industrial wastes average 0.67 mg Hg/kg wet wt. Levels in pike, perch, and walleye collected from four lakes without any known source of Hg pollution ranged from 0.11 to 1.13 mg Hg/kg wet wt. Authors suggest that these high Hg levels are probably of natural origin and related to Hg content of sedimentary bedrock.

2127. Sunda, W. and R.R.L. Guillard. 1976. The relationship between cupric ion activity and the toxicity of copper to phytoplankton. Jour. Marine Res. 34(4):511-529.

Culture experiments with the estuarine diatom Thalassiosira pseudonana in highly chelated seawater media demonstrate that growth rate inhibition and copper content of cells are altered independently of total copper concentration through varying chelator concentration and pH. Cellular copper content of 3 to 4 day old cultures followed a hyperbolic relation with cupric ion activity. Copper inhibited growth rate at activities above 0.002 µg/cell, with growth ceasing at values above 0.32 µg/cell. However, the relation between growth rate inhibition and cupric ion activity was not a simple hyperbolic function. In experiments with the estuarine green alga Nannochloris atomus, growth rate inhibition also was related to cupric ion activity with partial growth rate inhibition occurring in the activity range 0.003 to 0.128 µg/cell. Calculated estimates of cupric ion activity in seawater indicate that natural activity levels can be inhibitory to these phytoplankton depending on pH and the degree of copper complexation by natural organic ligands.

2128. Sutton, D.L., L.W. Weldon and R.D. Blackburn. 1970. Effect of diquat on uptake of copper in aquatic plants. Weed Science 18:703-707.

Combinations of copper sulfate pentahydrate (CSP) at 1.0 mg/kg dry wt Cu plus 0.1 to 2.0 mg/kg of the herbicide diquat resulted in higher accumulations of Cu in hydrilla (Hydrilla verticillata), egeria (Egeria densa) and southern naiad (Najas guadalupensis) when compared to plants receiving CSP only. Contact period greater than 24 hr was necessary before highest amounts of Cu were detected in plants treated with CSP and diquat. Water samples taken from outdoor plastic pools, 7 days after treatment with CSP at 1.0 mg Cu/kg dry wt, plus 1.0 mg/kg dry wt of diquat, contained 25% less Cu than pools treated with Cu alone. Samples of hydrilla and southern naiad removed 7 days after treatment with CSP and diquat contained 77 and 38% more Cu, respectively, than samples treated with CSP alone.

2129. Svansson, A. 1975. Physical and chemical oceanography of the Skagerrak and the Kattegat. I. Open sea conditions. Fishery Bd. of Sweden, Institute of Marine Research, Goteborg, Sweden, Rept. No. 1. 88 pp.

Mercury concentrations, (y) in mg/kg wet wt, are give [illegible] relation to fish wt, (x) in kg; for herring it was $y = 0.22x + 0.023$; flounder $y = 0.073x + 0.06$; plaice $y = 0.063x + 0.050$ for North Sea, but 0.025 mg/kg lower for the Kattegat; porbeagle Lamna nasus, $y = 0.05x$, and cod y = 0.025 x+ 0.17. Concentrations (in mg/kg wet wt) of cadmium ranged from 0.02 to 0.5; lead 0.1 to 3.0; zinc 3 to 17; and copper 0.6 to 3.6; zinc and copper values, given for herring, were somewhat lower than those for cod and plaice.

2130. Swader, J.A. and W.-Y. Chan. 1975. Citric acid enhancement of copper solubility and toxicity in bicarbonate solutions. Pesticide Biochem. Physiol. 5:405-411.

Toxicity of cupric ions to algal growth during the first 2 days of incubation was increased by the presence of citric acid in the growth medium (number of cells decreased from 1.27 x 10^{-6} ml with $CuSO_4$ to 1.12 x 10^{-6} ml with $CuSO_4$ plus citric acid). No adverse effects of citric acid on cupric sulfate as an algicide were detected. Sulfhydryls were oxidized in presence of cupric ions to disulfides with one mole of oxygen taken up for every 4 moles sulfhydryls oxidized. In bicarbonate solutions, this reaction was stimulated by addition of citric acid. Citric acid influence on copper solubility and cupric ion toxicity was not due to a pH effect.

2131. Swain, R. and P.S. Lake. 1974. The fenestra dorsalis of *Allanaspides* (Crustacea: Syncarida)—cytological changes in response to elevated NaCl levels. 8th Internat. Congress on Electron Microscopy. Canberra, Australia, Vol. II:246-247.

Changes in transport tissue of a fresh water crustacea were studied by transferring animals from natural water (Na = 0.17 meq/l) to similar water with added NaCl (Na = 4.36 meq/l), and observing changes in fenestra dorsalis after 1, 5, 10, 20, and 30 days. Final condition after 30 days is a pronounced reduction in surface area of both apical and basal transport systems and a much less efficient arrangement for water/ion movement.

2132. Sykora, J.L., E.J. Smith, M.A. Shapiro and M. Synak. 1972. Chronic effect of ferric hydroxide on certain species of aquatic animals. 4th Symposium on Coal Mine Drainage Research, Mellon Institute, Apr. 26-27, 1972, Pittsburgh, Penna.: 347-369.

Growth data of juvenile brook trout *Salvelinus fontinalis* kept for a full generation in 50, 25, 12, 6 mg Fe/l and control, showed a definite trend toward slower growth with increasing concentration of suspended ferric hydroxide; growth was greatest in the 6 mg Fe/l group and controls. Brook trout egg production decreased at high iron concentrations. This may reflect the importance of Fe as an inorganic nutrient, although at high levels excessive turbidity occurs which impairs visibility and feeding.

Fathead minnows Pimephales promelas were tested one year in concentrations of 50, 25, 12, 6, 3, 1.5 mg Fe/l, and control; these showed a decrease in growth and increase in mortality with increasing concentrations of Fe. Mortality was highest in 50 mg Fe/l (exceeding 50%) and also high in 25 and 12 mg Fe/l. The highest concentration of suspended iron which does not seem to affect survival and growth of fathead minnows was <12 mg Fe/l. However, spawning took place in 25 mg Fe/l, as well as in 1.5 mg Fe/l. Except for control and 50 mg Fe/l, on which there was no apparent effect, hatchability decreased as suspended Fe concentration decreased, with a 50% rise from 1.5 mg Fe/l to control. The only significant variable is the size of ferric hydroxide particles. Generally, the number of smaller particles decreases with higher concentrations. Smaller particles in low concentrations of suspended Fe may have clogged egg pores, resulting in low hatchability.

Gammarus minus (amphipod) and Cheumatopsyche (caddisfly) larvae were tested in the following two sets of concentrations: 100, 50, 25, 12, 6, 3 and 20, 10, 5, 2.5, 1.75, 0.80 mg Fe/l. Tests conducted with invertebrates show low susceptibility of Cheumatopsyche larvae to suspended ferric hydroxide, with adults emerging at the highest concentration tested of 20 mg Fe/l. Studies on Gammarus minus show a higher toxic effect of ferric hydroxide, especially to younger animals. The safe concentration for reproduction and growth of this species seems to be <3 mg Fe/l.

Results suggest that suspended iron produces high turbidities at high concentrations which interferes with feeding of teleosts and that low concentrations exert deleterious effects on the more susceptible eggs and hatched fry.

2133. Sykora, J.L., E.J. Smith, M. Synak and M.A. Shapiro. 1975. Some observations on spawning of brook trout (Salvelinus fontinalis, Mitchell) in lime neutralized iron hydroxide suspensions. Water Research 9:451-458.

Long-term effect of lime neutralized suspended iron at concentrations of 50, 25, 12, 6, 3, and 0 mg Fe/l on brook trout growth, survival, spawning, fecundity, and egg viability were assessed. Results of a 2 year study show low survival of maturing fish at concentration of ≥12 mg Fe/l and a decline in egg production at >12 mg/l due mainly to high winter mortality (40%) prior to spawning. Egg hatchability was unaffected at concentrations between 0.75 and 12 mg Fe/l. Safe levels of lime neutralized iron hydroxide suspensions for brook trout in an enclosed, intermittent-flow testing system lie between 7.5 and 12.5 mg Fe/l.

2134. Tagatz, M.E. 1971. Osmoregulatory ability of blue crabs in different temperature-salinity combinations. Chesapeake Sci. 12(1):14-17.

At salinities of 1.7, 17 and 34^{o}/oo and temperatures of 10, 20 and 30 C, salinity alone and salinity-temperature interactions affected total osmotic concentrations of blood for all life stages of blue crab; temperature alone did not affect response parameters. Ovigerous females did not regulate as well as mature females or adult males at 1.7 or 17^{o}/oo salinities. At almost all temperature-salinity combinations, however, differences in osmoregulatory ability of adult males and mature females were not significant. Differences in osmoregulatory capabilities are probably related to differences in distribution of lifestages and sexes.

2135. Talbot, V.W., R.J. Magee and M. Hussain. 1976. Cadmium in Port Phillip Bay mussels. Marine Poll. Bull. 7(5):84-86.

Cadmium levels, in mg/kg dry wt, ranged from 2 to 63 for mussels Mytilus edulis, and 36 to 174 for oysters Ostreidae angasi. Some values were in excess of the approximately 10 mg/kg dry wt (2 mg/kg wet wt) standard set by the Australian National Health and Medical Research Council.

2136. Tartar, V. 1957. Reactions of Stentor coeruleus to certain substances added to the medium. Experim. Cell Res. 13:317-332.

The comparatively large protozoan ciliate S. coeruleus reacts in specific and selective ways to compounds of sodium, lithium, magnesium, calcium, potassium and other chemicals. The major finding was that every chemical tested except ethyl alcohol caused stentors to shed the peristome within 20 minutes either in solution or upon return to culture fluid. Only in the case of ammonium acetate and $NiSO_4$ did all the animals, which cast off the peristome, fail to recover from treatment and regenerate a new set of feeding organelles when returned to normal medium. The effect was not attributable to ionic, viscosity, osmotic, or hydrogen ion effects.

2137. Taylor, D.D. and T.J. Bright. 1973. The distribution of heavy metals in reef-dwelling groupers in the Gulf of Mexico and Bahama Islands. Rept. TAMU-SG-73-208, Dept. Ocean., Texas A&M University, College Sta., Texas. 249 pp.

Groupers of family Serranidae from the Gulf of Mexico and Carribean were analyzed for Hg, As, Cd, Pb, Cu, and Zn. Mean muscle concentration of Hg, in mg/kg wet wt, ranged from 0.15 to 0.81 in *Epinephalus striatus*, 0.17 to 0.38 in *Mycteroperca tigris*, 0.41 to 0.60 in *E. cruentatus*, and 0.13 to 0.50 in *M. phenax*. For As these were 9.09 for *E. striatus*, 1.66 for *M. tigris*, 1.82 for *M. phenax*, and 1.36 for *E. guttatus*; for Cd these were 0.02 for *E. striatus*, 0.02 for *M. tigris*, 0.018 for *M. phenax*, and 0.024 for *E. guttatus*. Mean muscle concentrations of Pb (Cu) were 0.09 (0.31) for *E. striatus*, 0.06 (0.25) for *M. tigris*, 0.152 for *E. guttatus*, and 0.29 (0.23) for *M. phenax*. Mean muscle concentrations for Zn were 4.03 for *E. striatus*, 3.70 for *M. tigris*, and 3.17 for *M. phenax*. Correlation between concentrations of heavy metals and growth factors indicated differences between members of same species as well as interspecific differences. Hg and Zn increase with age and size in certain groupers where As shows no correlation. Interspecific differences reflect possible variations in feeding habits and metabolism; therefore, extrapolation from one species to another is invalid as is lumping species to represent a trophic level. High levels of arsenic in reef organisms which include crustacea, mollusks, echinoderms, polychaetes, porifera, algae, and other fish, appear to be related to substitution of arsenate for phosphate in biological systems. It is suggested that low phosphate reef waters can produce high magnification of arsenic by reef organisms.

2138. Templeton, W.L. and V.M. Brown. 1964. The relationship between the concentrations of calcium, strontium and strontium-90 in wild brown trout, *Salmo trutta* L. and the concentrations of the stable elements in some waters of the United Kingdom, and the implications in radiological health studies. Int. Jour. Air Water Poll. 8:49-75.

Respective Ca (Sr) concentrations in g/kg wet wt of trout tissues ranged from 45 to 80 (0.03 to 0.47) for bone; and 0.042 to 0.29 (0.00006 to 0.001) for muscle. Ca levels in bone and muscle were independent of water content while tissues levels were inversely related to Sr and Ca concentrations of water. In both bone and muscle, discrimination against Sr relative to Ca occurred. Trout and other species of freshwater fish contained 0.04 to 2.87 atoms Sr per 1000 atoms Ca. Aquatic higher plants (algae) had atoms Sr/1000 atoms Ca ratios of 0.66 to 5.2 (0.41 to 1.9). Sr/Ca ratio in fish and plants reflected Sr/Ca ratio of water. Accumulation factors for Sr in brown trout ranged from 3.2×10^4 in bone and 80 in muscle for waters of low Ca concentration, to 280 in bone and 1.0 in muscle tissue in high Ca waters. For Sr-90, degree of accumulation and relationship with Ca concentration of water is comparable with that of stable Sr.

2139. Thibaud, Y. 1971. Teneur en mercure dans quelques poissons de consommation courante. Sciences et Peche, Bull. Inst. Peches marit. 209:1-10.

Total mercury, in mg/kg wet flesh, was determined for various species of edible marine teleosts. Values were, in general, well below 0.33 mg/kg. However, some albacore tuna Neothunnus albacora contained up to 1.80 mg Hg/kg in white muscle, and up to 2.11 mg/kg in red muscle.

2140. Thibaud, J. 1973. Teneur en mercure dans les moules du littoral francais. Science et Peche, Bull. Inst. Peches marit. 221:1-6.

Two species of mussels, Mytilus edulis and M. galloprovincialis, collected from various stations along the entire French coast between December 1971 and October 1972 contained between 0.02 and 0.31 mg total mercury per kg wet wt.

2141. Thomas, A. 1915. Effects of certain metallic salts upon fishes. Trans. Amer. Fish. Soc. 44:120-124.

After 48 hr in 30 mg Cu/l as $CuSO_4$, killifish Fundulus heteroclitus contained 0.0035% Cu on a dry wt basis; all fish died by 96 hr. $CuCl_2$ was more toxic than $CuSO_4$ in a similar period. Tests with nickel chloride, ferric-ammonium-citrate and potassium dichromate showed that none were toxic at the highest concentration examined of 200 mg/l. Cobalt chloride, manganese chloride and zinc sulphate were also non-toxic at these levels, but mercuric chloride, cadmium nitrate and sodium arsenate were fatal at this concentration. Fundulus were present in an isolated nearly-freshwater pond which received salt water only during storms every two or three years. These fish were more sensitive to metals: mortalities occurred within 12 hrs at 3 mg/l lead nitrate; within 36 hrs at 14 mg/l aluminum sulphate; and within 5 days at 7 mg/l aluminum sulphate. Zinc sulphate was fatal within 48 hrs at 10 mg/l, but was non-toxic in seawater. Copper sulphate was fatal within 10 hrs at 4 mg/l; cadmium nitrate within 36 hr at 6 mg/l; nickel and cobalt chloride were lethal within 5 days at 16 mg/l and manganese chloride lethal in 6 days at 12 mg/l.

2142. Thomas, A.E. 1975. Marking channel catfish with silver nitrate. Prog. Fish-Cult. 37(4):250-252.

A preparation of 75% silver nitrate and 25% potassium nitrate was used to mark channel catfish Ictalurus punctatus. A pale mark results from cauterization of skin by caustic action of $Ag NO_3$ and is relatively permanent. KNO_3 sterilizes the mark area and prevents infection.

2143. Thomas, W.H. and A.N. Dodson. 1974. Inhibition of diatom photosynthesis by germanic acid: separation of diatom productivity from total marine primary productivity. Marine Biology 27: 11-19.

Germanic acid inhibited photosynthetic $^{14}CO_2$ uptake in marine diatoms, but inhibition was incomplete at concentrations of 20 mg Ge/l during 24 hr incubation. The decrease in photosynthesis due to $Ge(OH)_4$ was independent of growth stage of the culture. At 0.5 and 1.0 mg Ge/l, degree of inhibition was dependent on concentration of $Si(OH)_4$ in the medium. At 5 and 10 mg Ge/l, inhibition was not affected by $Si(OH)_4$ concentrations as high as those found in the sea (120 μg-atoms Si/l). The effect of $Ge(OH)_4$ on photosynthesis is specific for diatoms; other marine phytoplankters were not inhibited. In mixed cultures of diatoms and marine flagellates, the reduction in $^{14}CO_2$ fixation upon addition of $Ge(OH)_4$ was used to calculate proportion of diatom photosynthesis to total photosynthesis; calculated proportions agreed well with actual proportions. Inhibition by $Ge(OH)_4$ was also used to estimate percent of diatom photosynthesis in a natural marine community, and this was compared with the diatom portion of the crop. Diatom photosynthesis was higher than expected from crop figures, although both diatom photosynthesis and diatom numbers were low.

2144. Thompson, J.A.J., J.C. Davis and R.E. Drew. 1976. Toxicity, uptake and survey studies of boron in the marine environment. Water Research 10:869-875.

Little is known about toxicity and biomagnification to aquatic life posed by borate discharges from British Columbia ground wood pulp mills. Bioassays with underyearling coho salmon *Onchorhynchus kisutch* produced LC-50 (283 h) values of boron, as sodium metaborate, of 113.0 and 12.2 mg/l in fresh and saltwater, respectively. The disparity between freshwater and saltwater boron toxicity to coho is not understood at this time. Average B levels, in mg/kg wet wt, of sockeye salmon *O. nerka* in normal seawater were 0.6 for gills, 0.7 for liver, 0.6 for kidney, 0.5 for muscle and 1.5 for bone. After 3 weeks exposure of sockeyes to 10 mg B/l, tissue levels in mg B/kg wet wt were 5.6 for gills, 5.2 for liver, 7.3 for kidney, 3.8 for muscle, and 10.5 for bone. Oysters show no bioaccumulative potential or prolonged retention of boron following cessation of dosage. Mean B levels in mg/kg wet wt of various British Columbia marine bivalves, were: 3.8 for butter clam *Saxidomus giganteus*; 2.3 for little neck clams *Protothaca staminea* and *Venerupis japonica*; 3.5 for oysters *Ostrea lurida* and *Crassostrea gigas*; 3.0 for razor clam *Siliqua patula*; 4.5 for mussel *Mytilus californianus*; 3.5 for bay mussel *M. edulis*; 2.0 for cockle *Clinocardium nuttalli*; 3.0 for clam *Mya arenaria*; 1.6 for horse clam *Schizothoerus capax*; 1.3 for octopus *Polypus bimaculatus*; and 1.8 for crab *Cancer magister*.

Authors aver that at the present level of industrial discharge of boron ($\leq$1 mg B/l) there is no hazard to salmonoids or oysters.

2145. Thompson, T.G. and T.J. Chow. 1955. The strontium-calcium atom ratio in carbonate-secreting marine organisms. Deep-Sea Research 3(Suppl):20-39.

Strontium and calcium levels in 250 species of carbonate-secreting marine organisms including algae, protozoa, porifera, coelenterata, platyhelminthes, annelida, phoronidea, crustacea, mollusca, bryozoa, brachiopoda, echinodermata, and tunicata were determined. Sr-Ca atom ratio in calcareous portions ranged from 1.0 to 11 x 10^{-3}. With the exception of nudibranchs and corals, the atom ratio in marine organisms was less than seawater (8.9 x 10^{-3}). Sr-Ca atom ratios in marine organisms appeared to be constant in accordance with their phylogenetic classification. Similar types of marine organisms living under different environmental conditions from arctic to tropical oceans, showed constant Sr-Ca atom ratios. Variations in salinity and temperature of seawater apparently did not influence the Sr-Ca atom ratio in calcareous shells.

Mineralogical properties of calcium carbonate in marine organisms demonstrated a definite correlation with occurrence of Sr. Marine organisms containing calcium carbonate as aragonite had Sr-Ca atom ratios greater than calcite. Samples of deep-sea sediments and Globigerina ooze showed Sr-Ca atom ratios of 1.94 x 10^{-3} and 1.49 x 10^{-3}, respectively. Limestone deposits which originated from marine organisms had smallest Sr-Ca atom ratio (0.63 x 10^{-3}) of all materials examined. Apparently, matrix of calcareous deposits of marine origin has lost Sr during geological time.

2146. Thomson, A.J., J.R. Sargent and J.M. Owen. 1975. Effect of environmental changes on the lipid composition and (Na^++K^+)-dependent adenosine triphosphate in the gills of the eel, Anguilla anguilla. Biochem. Soc. Trans. 3:668.

Changes in lipid unsaturation and Arrhenius-plot discontinuity of (Na^++K^+)-dependent ATPase appear to result from changes in temperature but not salinity during migration of eels from fresh to seawater.

2147. Thorp, V.J. and P.S. Lake. 1973. Pollution of a Tasmanian river by mine effluents. II Distribution of macroinvertebrates. Int. Revue ges. Hydrobiol. 58:885-892.

The distribution and abundance of macroinvertebrates were studied in the South Esk River, Tasmania, which was impacted by cadmium and zinc wastes from mining operations. Groups most intolerant of Cd-Zn pollution were the crustacea, mollusca and annelida. Highly tolerant groups included aquatic hemiptera and arachnida, and larvae of leptocerid trichopterans. A drop in species diversity and biomass occurred after floods in winter; this may be due to pulses of cadmium and zinc discharged into the river and to increased molar action of the unstable substrate. One station at which no living organisms were found in summer or winter exhibited anomalously high levels of zinc (3.52 - 8.0 mg/l), cadmium (0.24 - 0.44 mg/l), copper (0.04 - 0.12 mg/l), manganese (0.97 - 4.7 mg/l), potassium (1.5 - 1.85 mg/l), calcium (6.0 - 17.6 mg/l), and magnesium (5.14 - 13.9 mg/l).

2148. Thrower, S.J. and I.J. Eustace. 1973. Heavy metal accumulation in oysters grown in Tasmanian waters. Food Tech. in Australia 25:546-553.

Abnormally high concentrations of zinc, cadmium, and copper were found in oysters Crassostrea gigas and Ostrea angasi grown in the Derwent and Tamar Estuaries. Individual oysters contained concentrations of zinc, cadmium, and copper as high as 21,000, 63, and 450 mg/kg wet wt, respectively. High concentrations of Zn and Cd in oysters from an area in the Derwent Estuary probably caused symptoms of nausea and vomiting experienced by some people after eating them. Oysters growing in areas where heavy metal pollution was expected to be minimal, showed levels of accumulation of zinc, cadmium, and copper up to 4000, 7.8, and 100 mg/kg wet wt, respectively. These were similar to levels reported from other parts of the world. None of the oysters examined complied with current food regulations (viz 40 mg/kg wet wt for Zn, 5.5 for Cd, and 30 for Cu).

2149. Thrower, S.J. and I.J. Eustace. 1973. Heavy metals in Tasmanian oysters in 1972. Austral. Fisher. 32(Oct. 1973):7-10.

Oysters accumulate certain toxic heavy metals if traces of these are present in surrounding waters; sites for commercial leases must be chosen with a full awareness of this possiblity. An exploratory survey of oysters from Tasmanian waters demonstrated unusual concentrations of cadmium, copper, and zinc in some oysters taken from leases close to Hobart and Launceston. Highest concentrations of Cu, Cd, and Zn determined in Tasmanian oysters were 123, 19, and 7670 mg/kg wet wt, respectively. The upper limits permitted by Tasmanian food regulations are, on a mg/kg wet wt basis, 30 for Cu, 5.5 for Cd, and 40 for Zn.

2150. Thurberg, F.P., W.D. Cable, M.A. Dawson, J.R. MacInnes and D.R. Wenzloff. 1975. Respiratory response of larval, juvenile and adult surf clams, Spisula solidissima, to silver. In Cech, J.J., Jr., D.W. Bridges and D.B. Horton (eds.). Respiration of Marine Organisms. TRIGOM Publ. S. Portland, Me.: 41-52.

Respiratory response of various life stages of surf clams during exposure to sublethal concentratios of silver (0.005 to 0.100 mg/l) was measured. When larvae reached length of 150 µ, those exposed to 0.05 mg Ag/l respired at rate of 12.5 µl O_2/hr/1000 larvae; control value was 9.4. Juveniles respired at a significantly higher rate than controls at 0.010 and 0.020 mg Ag/l, but not at 0.005 mg Ag/l. Adults respired significantly higher than controls at 0.050 and 0.100 mg Ag/l but not at 0.010 mg Ag/l. Mean silver concentration, in mg/kg wet wt, for clam body minus gills was 0.08 for controls, 1.01 for the 0.010 mg Ag/l group, 2.23 for 0.050 mg Ag/l and 2.00 for 0.100 mg Ag/l. For gills, mean Ag concentration in mg/kg wet wt was <0.63 for controls, 5.73 for 0.010 mg Ag/l, 8.72 for 0.050 mg Ag/l, and 8.52 for 0.100 mg Ag/l. Valve movements of 8 control clams and 8 clams during exposure for 96 hrs to 0.050 mg Ag/l were recorded: exposed animals averaged 24.6 movements or partial closures per hour, while controls averaged 12.0.

2151. Thurberg, F.P., A. Calabrese and M.A. Dawson. 1974. Effects of silver on oxygen consumption of bivalves at various salinities. *In* Vernberg, F.J. and W.B. Vernberg (eds.). Pollution and Physiology of Marine Organisms. Academic Press, New York: 67-78.

Oxygen consumption of American oysters *Crassostrea virginica* at 25 and 15^{o}/oo salinity was 1.1 and 1.15 µl O_2/hr/mg, respectively. This increased to 1.3 and 1.7 µl O_2/hr/mg during exposure for 96 hrs to 1.0 mg silver/l; silver did not affect O_2 consumption at 35^{o}/oo. Oxygen consumption rates of quahaugs *Mercenaria mercenaria*, held at 25 and 35^{o}/oo salinity increased from 1.2 to 1.6 µl O_2/hr/mg during exposure to 1.0 mg Ag/l for 96 hrs; silver did not affect oxygen consumption rate of quahaug held at 15^{o}/oo. Mussels *Mytilus edulis* exhibited increases from 1.2 and 1.8 to 2.0 and 3.0 µl O_2/hr/mg at salinities of 25 and 15^{o}/oo, respectively, during exposure to 1.0 mg Ag/l for 96 hrs. At 25 and 35^{o}/oo salinities, soft-shelled clams *Mya arenaria* died at 1.0 mg Ag/l; *Mya* held at 15^{o}/oo increased respiration rates from 1.6 to 3.2 µl O_2/hr/mg upon identical Ag addition. Ag concentrations of 0.1 mg/l increased consumption rates for all species showing significant rate changes at 1.0 mg Ag/l.

Lamellibranchs collected within 1.6 km of Milford Harbor, Connecticut showed the following Ag concentrations in mg/kg wet wt: 6.1 in body, 5.9 in gills of *C. virginica*; 0.4 in body, 1.6 in gills of *M. mercenaria*; 0.2 in whole *M. edulis*; and 0.3 in whole *M. arenaria*. During 96 hr exposure to 1.0 mg Ag/l, silver content increased to 14.9 in body and 33.9 in gills of *C. virginica*; 1.0 in body and 6.9 in gills of *M. mercenaria*; and 5.2 in whole *M. edulis*.

2152. Tingle, L.E., W.A. Pavlat and I.L. Cameron. 1973. Sublethal cytotoxic effects of mercuric chloride on the ciliate *Tetrahymena pyriformis*. Jour. Protozool. 20(2):301-304.

Behavior and ultrastructure of *T. pyriformis* was assessed after exposure to dosages of 0.25 mg/l and 0.50 mg/l $HgCl_2$, which is 8 and 16% respectively of the LC-50 (96 hr) concentration. The lower dosage caused no abnormal changes in cell motility, contractile vacuole activity or cell shape. Higher dosage caused reduced cell motility and increased activity of contractile vacuole. Seventy-five percent of cells in higher dosage had swollen and distorted mitochondria; 70% had membraneous swirls inside the outer membrane of pellicle; macronucleus had condensed chromatin, with chromatin bodies moved or displaced from nuclear envelope. At the lower $HgCl_2$ dosage, extensive changes involving mitochondria occurred after 1-hr exposure; these were repaired after 24 hrs of exposure indicating adaption to toxicant. Authors attempt to apply findings and cytotoxic evidence to define a "safe" concentration of $HgCl_2$.

2153. Tolkach, V.V., V.V. Gromov and V.I. Spitsyn. 1975. An investigation of absorption of ^{137}Cs by krill. Doklady Biol. Sci. Proc. Acad. Sci. USSR 220:11-13.

From 15 to 20% of Cs-137 (initial dosage 1 m Ci) was absorbed in 1.5 days by these Antarctic crustaceans when added to 8.6 to 30.9 g krill/l of seawater. Mean coefficient of accumulation for small krill was 324 per wt of heat-dried krill and 9 per dry wt; for large krill it was 103 per wt of heat-dried krill and 3 per dry wt. Cs-137 entrapment was proportional to volume of krill alimentary organs.

2154. Tompkins, T. and D.W. Blinn. 1976. The effect of mercury on the growth rate of *Fragilaria crotonensis* Kitton and *Asterionella formosa* Hass. Hydrobiologia 49:111-116.

Effects of $Hg(NO_3)_2$ and $HgCl_2$ on two species of freshwater planktonic diatoms showed that growth of *Fragilaria* was totally inhibited at 0.1 mg/l and that a 4 day increase in lag phase occurred together with a 2-4X reduction in growth rate at 0.05 mg/l. *Asterionella* showed a gradual increase in lag phase and reduction in growth rate with increasing concentrations of Hg up to 0.25 mg/l. *Asterionella* growth was totally inhibited at 0.5 mg/l. Hg salts in cultures of both species with soil extract additives were significantly less toxic. Cultures of *A. formosa* deviated from the typical 8-16 celled stellate colony at sublethal concentrations to form large cylindrical stacks composed of 25 to 30 colonies.

2155. Tonomura, K., K. Maeda, F. Futai, T. Nakagami and M. Yamada. 1968. Stimulative vaporization of phenylmercuric acetate by mercury-resistant bacteria. Nature, London 217:644-646.

An experiment was conducted in which a large amount of phenylmercuric acetate (PMA) was absorbed by mercury-resistant bacteria. Using Hg-203 labelled PMA, it was found that cell-bound radioactivity disappeared rapidly from culture before onset of growth. Free PMA rarely disappeared from solution under the same conditions. When organisms were incubated directly with Hg-203 labelled PMA, disappearance of radioactivity from the culture was also observed. PMA may be bound to bacterial surfaces and then biologically stimulated to initiate vaporization of Hg. Vaporization was not stimulated by heated cells, disrupted cells or cells treated with acetone or toluene. Vaporization was inhibited at PMA concentrations greater than 150 mg/l and enhanced by cells pre-incubated with PMA. Authors suggest two mechanisms of vaporization. One in which it is stimulated by a gaseous substance evolved from bacterial surface on which PMA is bound. The second is a chemical conversion of PMA to a substance more volatile than PMA.

2156. Topping, G. 1973. Heavy metals in shellfish from Scottish waters. Aquaculture 1:379-384.

Concentrations of Cu, Zn, Pb and Cd in edible tissues of shellfish taken from Scottish coastal waters were determined. Lead in mg metal per kg wet wt ranged from <0.2 to 5.5 in mussel Mytilus edulis; <0.1 to 2.8 in periwinkle Littorina littorea; <0.1 to 1.0 in scallop Pecten maximus; <0.2 to 0.5 in spiny lobster Nephrops norvegicus; <0.4 in lobster Homarus vulgaris; and <0.8 in crab Cancer pagurus. Cadmium ranged from 0.1 to 2.0 in mussel, 0.03 to 0.05 in periwinkle, 5.1 to 23.0 in scallop, <0.03 to 0.1 in spiny lobster, <0.03 to 0.09 in lobster and 3.6 to 13.0 in crab; highest values were in kidney and liver of scallop, lobster and crab. Copper ranged from 0.5 to 5.0 in mussel, 6.2 to 20.0 in periwinkle, 0.4 to 0.9 in scallop, 2.1 to 11.3 in spiny lobster, 6.2 to 13.2 in lobster and 8.0 to 125.0 in crab; highest Cu values were in kidney and liver of individual shellfish. Zinc was lowest in spiny lobster at 8.5 to 12.2 and highest in crab at 21.3 to 34.5. Zinc ranged from 12.5 to 82.5 in mussel, 6.6 to 20.2 in periwinkle, 19.1 to 45.5 in scallop and 13.8 to 16.7 in lobster. Zn concentration in all shellfish examined was higher than Pb, Cu or Cd concentration. It was concluded that variations in metals content observed were attributable to natural effects rather than anthropogenic perturbations.

2157. Towle, D.W. 1974. Equivalence of gill $Na^+ + K^+$ - ATPases from blue crabs acclimated to high and low salinity. Amer. Zool. 14:1259.

Male blue crabs *Callinectes sapidus* were acclimated to salinities of 34 and 5^{o}/oo. Microsomal preparations of gills from these animals had $Na^{+} + K^{+}$ -ATPase activities of 1.29 and 2.33 µmoles P_i/mg protein/min, respectively, implicating $Na^{+} + K^{+}$ -ATPase in the previously recognized ability of crab to regulate hyperosmotically in dilute seawater. The possibility of two unique $Na^{+} + K^{+}$ -ATPases was discounted by comparing properties of enzymes isolated from crabs acclimated to two different salinities. Enzymes from both sources were highly sensitive to ouabain and required either K^{+} or NH_4^{+} as well as Na^{+}. Sodium-dependent phosphorylation of both enzymes by labelled ATP-32 was blocked by K^{+} or NH_4^{+}. Polyacrylamide gel electrophoresis of SDS-solubilized P-32 labelled $Na^{+} + K^{+}$ -ATPases showed one band of radioactivity in each case. This phosphorylated protein had an apparent molecular weight of 100-105,000 and represented over 30% of the total microsomal membrane protein in each preparation.

2158. Townsley, S.J. 1954. Studies on copper in mollusks, with particular reference to *Busycon canaliculatum* Linnaeus. Ph.D. Thesis. Yale Univ., New Haven, Ct. 126 pp.

Average levels of copper, in mg/kg wet wt, of channeled whelks were: gut 248; liver 146; kidney 76; pancreas 76; buccal mass 44; gill 40; gonad 21; heart 16; and foot 8. Similar Cu distributions were found in *Nassa obsoleta* and *Littorina littorea* though kidneys had less and pancreas more Cu than *Busycon* organs. Cu values in mg/kg wet wt ranged from 35 to 83 for blood, 67 to 137 for hemocyanin, and 3 to 40 for supernatant in *Busycon*. Cu was histochemically demonstrated only in green pigment granules of cells of connective tissue surrounding and invading gut, liver, pancreas and gonad. Accumulation of Cu-64 by other organs in quantities not ascribable to activity of included blood demonstrated that Cu was not due to occluded blood. Cu was either in a more soluble form removed in histological preparation, or more strongly bound chemically than Cu of pigment cells and thus incapable of histochemical detection. Kidney, gill, heart, gonad and possibly buccal mass had rapid Cu turnover rates; turnover may be associated with Cu enzymes present. Relative activity of gut indicated involvement in Cu excretion; pancreas and liver had low apparent Cu metabolisms and stored any Cu accumulated. Injected Cu-64 circulated to tissues in combination both with hemocyanin and smaller molecules of the supernatant fraction. Cu was transferred from blood to tissues within 24 hrs after injection, although subsequently returned to blood or excreted. Injected Cu-64 exchanged with Cu already present in blood fractions. It is suggested that Cu-64 may exchange with Cu at active sites on hemocyanin molecules or become bound to smaller supernatant fraction molecules. Cu in hemocyanin was in equilibrium with that of supernatant fraction. Only 4-8% resynthesis of hemocyanin occurred by 24 hrs after animals were bled. Failure of Cu-64 activity of blood to drop at 24 hrs in bled animals indicated that less Cu-64 was transferred to tissues and utilized in synthesis of new hemocyanin units.

2159. Tripp, M. and R.C. Harriss. 1976. Role of mangrove vegetation in mercury cycling in the Florida everglades. In Nriagu, J.D. (ed.). Environmental Biogeochemistry. Vol. 2. Metals Transfer and Ecological Mass Balances. Ann Arbor Sci. Publ., Ann Arbor, Mich.: 489-497.

Field studies on mercury accumulation by detrital mangrove leaves Rhizophora mangle showed a 10X Hg enrichment of decomposing mangrove material during initial submergence and leaching by water, and during transition from leached leaf tissue to fine-grained particulate organic sediment. Samples collected during periods of low freshwater discharge, i.e. during periods of high salinity in mangrove environment, exhibited higher Hg concentrations in most tissue and sediment samples relative to samples collected during the wet season and from mangroves exposed to low salinities, i.e. 1 to 12^{o}/oo. Tannin concentrations in mangroves decreased about 10X when leaves were subjected to subaqueous leaching, in an inverse relationship to Hg. A laboratory experiment designed to simulate decomposition of mangrove leaves under controlled conditions showed that Hg content of decomposing mangrove leaves increased from 90 nannograms/g dry wt in fresh leaves to 120-140 nannograms/g dry wt in tissue leached for 15 days. Tannin content of leaves decreased from 115 mg/g to 78 mg/g, simulating changes in natural system. This supports a model that attributes initial Hg enrichment to loss of soluble cellular materials which are low in Hg with a consequent relative increase in Hg per unit wt of tissue in cell fractions resistant to decomposition. Approximately 10-11% of tissue Hg is associated with cellular fluids and components which are released during breakdown of cells. About 90% of total leaf Hg is concentrated in cell wall materials which are not readily degraded. It was stated that cell wall may be the primary site for deposition of non-essential trace metals.

2160. Trollope, D.R. and B. Evans. 1976. Concentrations of copper, iron, lead, nickel and zinc in freshwater algal blooms. Environ. Pollution 11:109-116.

Algae were collected from areas adjacent, near, or distant from zinc smelting wastes in the lower Swansea Valley in Wales. Algae showed decreasing zinc concentration with increasing distance from probable zinc sources. Copper concentrations in adjacent and distant waters were similar, but mean Cu, Fe, Ni and Pb values in near waters were about 2X those in adjacent waters. Majority of algal blooms were filamentous and all were Chlorophyta except two. Seven adjacent blooms contained very high Zn and Pb compared with seven distant blooms, mean values being 25X greater. With one exception, metal levels were adjacent > near > distant. The exception was Ni where high mean value for near algae was due to high value in the Cyanophyte Oscillatoria. Mean concentration factors for Zn were higher at distant > adjacent > near, whereas Cu, Fe, and Pb were adjacent > near > distant and Ni was near > adjacent > distant. For the three groups, mean metal concentrations were ordered Fe > Zn > Pb > Cu > Ni. For individual water masses there were: Fe > Zn > Ni, Pb > Cu in distant areas; Zn > Ni > Pb > Fe > Cu in near; and, Zn > Pb > Fe > Ni > Cu in adjacent waters.

2161. Truchot, J.P. 1973. Fixation et transport de l'oxygene par le sang de Carcinus maenas: variations en rapport avec diverses conditions de temperature et de salinite. Netherlands Jour. Sea Res. 7:482-495. (In French, English summary)

Increased temperature and decreased salinity diminished O_2-affinity of blood respiratory pigment in crabs. Increased temperature resulted in P_{50}, the partial pressure of O_2 at half saturation, by simple thermodynamic effect and by control of blood pH at lower values. Decreasing salinity resulted in blood dilution, augmenting the P_{50}. In vivo compensations occurred which maintained P_{50} between 7 and 12 torr. These compensations were related to rise of blood pH accompanying the decrease of salinity. P_{50} showed a significant decrease at temperatures above 20 C and this may be due to ion exchange between internal and ambient media.

2162. Tsubaki, T., T. Sato, K. Kondo, K. Shirakawa, K. Kanbayashi, K. Hirota, K. Yamada and I. Murone. 1967. Outbreak of intoxication by organic mercury compound in Niigata Prefecture. An epidemiological and clinical study. Jap. Jour. Med. 6(3):132-133.

A second outbreak of organic mercury compound intoxication among inhabitants along the Agano River, Japan, occurred between August 1964 and July 1965. Symptoms included numbness, hearing difficulties, cerebellar ataxia, speech disturbances, visual field constriction and disturbance of gait. Levels of Hg in hair of villagers correalted with amount of Agano River fish eaten.

2163. Tsuruga, H. 1963. Tissue distribution of mercury orally given to fish. Bull. Japan. Soc. Sci. Fish. 29(5):403-406. (In Japanese, English summary)

Freshwater (carp) and marine (conger eel) teleosts were fed mussels and clams labelled with Hg-203Cl. Previous studies indicated that mussel will concentrate mercury by a factor of 660 in 4 days and clam 190X in 8 days from seawater containing 0.05 mg Hg/l. Similar patterns were observed among carp fed mussel for 17 days and eels fed clams for up to 19 days. Hg concentrated in fish kidney, gill, liver, and bone; content in muscle was low (0.03 to 0.5 mg/kg). This study does not support the high mercury content found in fish from (the mercury-impacted) Minamata Bay; however, the form in which the mercury was administered in the present study (inorganic) was probably different from the chemical species encountered by Minamata Bay fish and shellfish (organic).

2164. Turekian, K.K. and R.L. Armstrong. 1960. Magnesium, strontium, and barium concentrations and calcite-aragonite ratios of some recent molluscan shells. Jour. Marine Res. 18(3):133-151.

Aragonitic shells of pelecypods contained 53 to 320 mg/kg of Mg, 1000 to <5000 of Sr, and 4 to 41 of Ba. For *Pecten*, shells were 80 to 100% calcite containing 440 to 4700 mg/kg of Mg, 660 to 1200 of Sr, and 6 to 12 of Ba. Gastropods contained Mg, Sr, and Ba levels of 38 to 4300 mg/kg (Mg), 860 to 2700 (Sr), and 4 to 15 (Ba). Percent calcite content ranged from 0 to 75%. Authors suggest that simple ionic size may control incorporation of trace alkaline-earths in shells.

2165. Turekian, K.K., J.K. Cochran, D.P. Kharkar, R.M. Cerrato, J.R. Vaisnys, H.L. Sanders, J.F. Grassle and J.A. Allen. 1975. Slow growth rate of a deep-sea clam determined by ^{228}Ra chronology. Proc. Nat. Acad. Sci. U.S.A. 72(7):2829-2832.

The age of a deep-sea clam, *Tindaria callistiformis*, from 3800 m depth has been determined by Ra-228 (6.7 year half-life) chronology of separated size fractions of a captured population. Assuming growth laws for shallow water bivalves hold for deep water forms, a length of 8.4 mm is attained in about 100 years implying that gonad development begins at age 50-60 years (4 mm). Shells of this size fraction show about 100 regularly spaced bands, indicating that the growth feature may be an annual one.

2166. Tyler, P.A. and R.T. Buckney. 1973. Pollution of a Tasmanian river by mine effluents. I. Chemical evidence. Int. Rev. Ges. Hydrobiol. 58:873-883.

Discharge of sulfuric acid, Zn, Cd, Cu, Pb, Fe and Mn in either dissolved or particulate form from tin and wolfram mines has led to destruction of normal biota in two creeks in North-East Tasmania. Brown trout *Salmo trutta* were unable to survive, and benthic algae were uncommon. Creek water was unsuitable for domestic or agricultural use.

2167. Ueda, T., R. Nakamura and Y. Suzuki. 1976. Comparison of ^{115m}Cd accumulation from sediments and seawater by polychaete worms. Bull. Japan. Soc. Sci. Fish. 42:299-306.

Deposit-feeding marine worms *Nereis japonica* directly in contact with Cd-115m sediments accumulated 6X more Cd-115m than worms not in contact with Cd-115m sediments during an 8 day period. Dividing the concentration factor of 22 (from seawater) by 0.12 (the value of Cd-115m accumulation by direct contact from sediments), an assumed biological factor of 200 for sediments is obtained. This suggests that sediments and seawater would affect worm residues equally when level of Cd-115m in sediments is 200X higher than seawater, and seawater levels decrease by dilution and diffusion. Distribution of Cd-115m in seawater, sediments and alga were examined using a theoretical mathematical mode; it was determined that activity ratios of Cd-115m were 9 for sediments and 21 for alga, which was similar to 22 for worms.

2168. Ui, J. 1971. Mercury pollution of sea and fresh water its accumulation into water biomass. Rev. Intern. Oceanogr. Med. 22-23:79-128.

Histories of mercury poisoning cases in Japan are examined. Article also reviews past research on methyl-Hg, including role of fish and bacteria in coastal environments of Italy, Germany, Sweden, Finland, Canada, U.S.A. and Holland.

2169. Ukeles, R. 1962. Growth of pure cultures of marine phytoplankton in the presence of toxicants. Appl. Microbiol. 10:532-537.

Effects of 17 toxicants, which included organic phosphates, phenolics, oils, iodophor, chlorinated hydrocarbons, carbamates, urea derivatives and Lignasin (ethyl mercury phosphate), on the growth of *Monochrysis lutheri*, *Dunaliella euchlora*, *Chlorella* sp., *Protococcus* sp., and *Phaeodactylum tricornutum* were studied. Lignasin was the most toxic compound; 0.06 mg/l was lethal to all species; the only concentration tested which did not cause drastic inhibition of growth was 0.0006 mg/l.

2170. Ulrikson, G.U., D.J. Nelson and N.A. Griffith. 1971. The effect of temperature on elimination rates of Cs-137 in bluegill (*Lepomis macrochirus*). *In* Oak Ridge Nat. Lab. Ecol. Sci. Div. Ann. Prog. Rep., ORNL-4634:106-107. Available from NTIS, U.S. Dept. Comm., Springfield, Va.

Experimental data support the theory that there is a doubling in rate of Cs-137 elimination with each 10 C increase in temperature. Small fish eliminated Cs-137 more rapidly than large fish.

2171. Updegraff, K.F. and J.L. Sykora. 1976. Avoidance of lime-neutralized iron hydroxide solutions by coho salmon in the laboratory. Environ. Sci. Technol. 10:51-54.

Salmon *Oncorhynchus kisutch* raised in clean water showed no avoidance of suspended lime-neutralized iron hydroxide suspensions containing up to 1.20 mg Fe/l. Higher concentrations produced increased avoidance, until a definite avoidance reaction was observed at 4.25-6.45 mg Fe/l. Adaptation is possible: fish exposed for several months to different iron hydroxide concentrations showed responses almost identical to those of controls.

2172. Ussing, H.H. 1947. Interpretation of the exchange of radiosodium in isolated muscle. Nature 160:262-263.

Isolated frog sartorii muscle were equilibrated with radiosodium. Exchange of Na in muscle fibers with outside medium occurred at more than 150 cal/kg/hr. Several possible mechanisms which allow for exchange of sodium ions without consumption of energy are discussed.

2173. Uthe, J.F. and E.G. Bligh. 1971. Preliminary survey of heavy metal contamination of Canadian freshwater fish. Jour. Fish. Res. Bd. Canada 28:786-788.

For lake whitefish *Coregonus clupeaformis*, northern pike *Esox lucius*, rainbow smelt *Osmerus mordax*, and yellow perch *Perca flavescens*, collected from non-industrialized and heavily industralized freshwater regions of Canada, muscle residues in mg/kg wet wt, were: <0.5 for Pb; <0.2 for Ni; 0.5 to 1.28 for Cu; 0.0022 to 0.0043 for Sb; $\sim$0.05 for Cd; 11 to 20 for Zn; <1 to 3 for U; 0.02 to 3.16 for Mn; 0.17 to 0.38 for Se; <0.017 to 0.035 for Cr; and 0.55 to 5.43 for Sn. For most of these elements, residues did not differ significantly between regions. Arsenic and Hg levels ranged from 0.05 to 0.70 mg/kg wet wt, with highest values observed in the industrial area.

2174. Váczi, L., M. Fodor, H. Milch and A. Réthy. 1962. Studies on the mercuric chloride resistance of *Staphylococcus aureus*. Acta Microbiologica 9:81-87.

Of 409 *S. aureus* strains 34% were sensitive, and 66% resistant to mercuric chloride. Incidence of $HgCl_2$-resistant cultures among antibiotic sensitive staphylococci was 20%; among strains resistant to penicillin or more than one antibiotic this was 70%. $HgCl_2$-resistant organisms occurred chiefly among phage group I and untypable strains; they were especially common among "epidemic" strains of phage group I, and among cultures resistant to 4-6 antibiotics. A 30X difference in $HgCl_2$ sensitivity and a 2X difference in merthiolate sensitivity was found among the strains. Sulfhydryl content of $HgCl_2$ resistant organisms was only 1.5X greater than that of sensitive bacteria. A 2X difference was found between the p-chlor mercuric benzoate binding capacity of $HgCl_2$ sensitive vs resistant bacteria. Differences in $HgCl_2$ resistance of staphylococcal strains might be due to differences in chemical structure of cell surface.

2175. Vaituzis, Z., J.D. Nelson, Jr., L.W. Wan and R.R. Colwell. 1975. Effects of mercuric chloride on growth and morphology of selected strains of mercury-resistant bacteria. Appl. Microbiol. 29(2):275-286.

Mercury resistance was dependent upon ability to volatize mercury from medium and upon amount of mercury accumulated by cells. Most cultures which adapt to growth in presence of $HgCl_2$, exhibit extensive morphological abnormalities. Significant effects include delay in onset of growth and cell division, and numerous structural irregularities associated with cell wall and cytoplasmic membrane synthesis and function. Detailed analysis of adaptation process and resulting effects on morphology was performed on an Enterobacter sp. During the period preceding active multiplication, selection for mercury-resistant mutants occurred. It was also demonstrated that growth commenced only at a specific threshold concentration of 1.1 ug/ml Hg^{2+}.

2176. Valiela, I., M.D. Banus and J.M. Teal. 1974. Response of salt marsh bivalves to enrichment with metal-containing sewage sludge and retention of lead, zinc and cadmium by marsh sediments. Environ. Pollut. 7:149-157.

Growth in clam Mercenaria mercenaria, and oyster Crassostrea virginica in tidal creeks of salt marshes on the NW Atlantic coast, was not affected by experimental additions of metal-containing sewage sludge and urea fertilizers to salt marsh plots. Modiolus demissus, a mussel inhabiting the marsh surface, grew better under the same fertilizer treatments. All 3 species of shellfish showed no increases in lead or zinc contents, but all showed increased cadmium contents related to sludge fertilizer treatments. Increases in Zn, and particularly Cd, but not Pb, were detected in creek bottom detritus downstream from the plots. Surface sediments of marsh plots show significant accumulation of all 3 metals. The calculation of input-output budgets shows that Pb was trapped in sediments with virtually no losses to deeper waters. Zinc and Cd also accumulated in sediments but there is some transport away from salt marsh surface, especially with cadmium. Highest concentrations of metals recorded in clam in mg/kg dry wt were: 3.5 for Pb, 298 for Zn, and 2.18 for Cd. For oyster these were <1, 12,675, and 9.45 for Pb, Zn, and Cd, respectively. For mussel it was 3.2 for Pb, 52 for Zn, and 7.13 for Cd.

2177. Vanderploeg, H.A., R.S. Booth and F.H. Clark. 1975. A specific-activity and concentration model applied to cesium movement in an oligotrophic lake. In Howell, F.G., J.B. Gentry, and M.H. Smith (eds.). Mineral cycling in southeastern ecosystems. U.S. Energy Res. Dev. Admin.: 142-165. Avail. as CONF-740513 from NTIS, U.S. Dept. Comm., Springfield, Va. 22161.

A linear systems-analysis model was derived to simulate time-dependent dynamics of specific-activity and concentration of radionuclides in aquatic systems. Transfer coefficients were determined for movement of Cs-137 in water, sediments, interstitial water, algae, insect larvae, and fish of three trophic types in an oligotrophic lake. Simulations with a model that ignored sediment-water interactions predicted much higher Cs-137 activities in water and biota than in the complete model. Comparing predicted Cs-137 concentrations with reported concentrations in biota of an experimentally contaminated lake indicated that derived transfer coefficients are adequate.

2178. van Someren, V.D. 1937. A preliminary investigation into the causes of scale absorption in salmon (Salmo salar Linne). Fish. Bd. Scotland Salmon Fish. No. 2:1-12.

During migration, serum Ca level in female salmon rose from 20 to 40 mg%; at spawning it dropped to 12 mg%. Serum Ca in male salmon remained at 16 mg% until spawning, when it also fell to 11 mg%. Variations in serum Ca was independent of weight, length, condition, and degree of scale absorption; authors suggest that it is a secondary phenomenon incidental to pituitary activity and growth of gonads. Blood Ca was probably not derived from the scales. Major cause of scale absorption is attributed to potential mineral deficiency during migration fast. In male salmon, absorption is probably accentuated by a demand for Ca necessary for development of secondary sexual characteristics.

2179. Velimirov, B. and E.L. Böhm. 1976. Calcium and magnesium carbonate concentrations in different growth regions of gorgonians. Marine Biology 35:269-275.

Four abundant gorgonian (coelenterate) species from SW Cape of Good Hope waters, Eunicella papillosa, E. alba, E. tricoronata, and Lophogorgia flamea were analyzed for Ca and Mg. Total mineral content in peripheral tissues, excluding axial skeleton, expressed as sum of $CaCO_3$ and $MgCO_3$ on a dry wt basis ranged between 65 and 83%. Mineral content varied in different growth regions; all specimens showed a higher degree of mineralization at the base than at branch tips. $MgCO_3$ concentration varied with genus and species and ranged between 9 and 11 mol %. Variation of $MgCO_3$ concentration within different growth regions of the same species was small, and generally did not exceed 0.8 mol %. From branch to stem, $CaCO_3$ and total mineral content increased. The $CaCO_3$:$MgCO_3$ ratios in different growth regions of all species indicated that composition of mesoskeleton with regard to relative concentration of $CaCO_3$ and $MgCO_3$ is constant throughout animal. Mineralogically, mesoskeleton consists of high magnesian calcite as identified by X-ray diffraction. The $MgCO_3$ data in gorgonian samples from cold Atlantic Ocean and warmer Indian Ocean show a linear relationship between water temperature.

2180. Vernberg, W.B., P.J. DeCoursey and J. O'Hara. 1974. Multiple environmental factor effects on physiology and behavior of the fiddler crab, *Uca pugilator*. *In* Vernberg, F.J. and W.B. Vernberg (eds.). *Pollution and physiology of marine organisms.* Academic Press, Inc., New York: 381-425.

Effects of cadmium and mercury salts on *Uca* depend on many factors including stage of life cycle, sex, thermal history, and environmental regime. The two metals do not necessarily affect *Uca* in the same manner. Larvae are several orders of magnitude more sensitive to mercury than adult stages, and adult males are more sensitive to mercury than females. Mercury is most toxic at low temperatures and low salinity. Warm-acclimated animals (summer animals) are less tolerant of Hg at low temperatures than cold-acclimated (winter) ones, and concentrations of Hg that are sublethal under optimum conditions of temperature and salinity become lethal with suboptimal thermosaline regimes. Distribution of Hg in crab tissues is dependent on environmental regime, but total body burden is not. Adult crabs are also less sensitive to cadmium poisoning than larvae, but there were no observed differences in mortalities between males and females. Cadmium is most toxic at high temperature and low salinity, and both the distribution and total body burden of cadmium is dependent upon environmental conditions. Although there are major differences in uptake and accumulation of Hg and Cd, it is stated that with both elements death is probably related to accumulation of metal in gills with an associated breakdown in osmoregulation or respirating functions.

2181. Vijayamadhavan, K.T. and T. Iwai. 1975. Histochemical observations on the permeation of heavy metals into taste buds of goldfish. Bull. Jap. Soc. Sci. Fish. 41:631-639.

Taste buds located in palatal organs of goldfish *Carassius auratus* were exposed for 3, 10, 15, 30, and 60 minutes to 10^{-4}M solutions of mercuric chloride, copper sulphate and zinc chloride (24 mg/l, 16 mg/l and 10 mg/l solutions, respectively), and 10^{-3}M solutions of copper sulphate, zinc chloride and lead nitrate (160 mg/l, 100 mg/l and 269 mg/l solutions, respectively). Rate of metal-permeation into taste cells varied with metal, concentration of metallic ions in medium, and duration of exposure. In terms of permeation rate the sequence of metals was found to be Hg, Cu, Zn, and Pb. Hg damaged not only taste buds but entire epithelial layers within 30 min; Cu effects were more or less confined to taste buds. Both Hg and Cu caused vacuolation at the bases of taste buds. Pb affected mucous cells more than taste buds. Results suggest that histological damage is associated with and preceded by metal-permeation. During the early phase of exposure, Hg, Cu (10^{-4}M), and Zn (10^{-3}M) selectively permeated certain taste bud cells.

2182. Vink, G.J. 1972. Koper in vis (copper in fish). TNO Nieuws 27:493-496. (In Dutch, English summary)

Copper levels in muscle of young flatfish collected in Dutch coastal waters ranged from 1.3 to 6.7 mg/kg dry wt. Age, condition, and location of collection were all significant factors affecting Cu residues.

2183. Vinogradova, Z.A. and V.V. Koual'skiy. 1962. Elemental composition of the Black Sea plankton. Doklady Acad. Sci. U.S.S.R. Earth Sci. Sec. 147:217-219.

Respective maximum concentrations of elements, in g/kg ash wt, of 1) diatoms, 2) copepods, 3) chaetognaths (*Sagitta*), and the 4) ctenophore (*Pleurobranchia pileus*) were: beryllium 0.003, 0.003, nd (not detected), and nd, respectively; for lead 3, 0.15, 1.5 and 0.04; tin 0.1, 0.07, 0.4 and 0.02; gallium 0.02, 0.04, 0.01 and nd; molybdenum nd, 0.05, nd, and nd; lithium 0.15, 0.4, 0.5 and 0.6; copper 100, 15, 30 and 0.3; silver 0.03, 0.03, 0.06 and 0.004; nickel 0.15, 0.2, 0.3 and 0.05; cobalt 0.015, 0.015, nd and nd; zirconium 0.05, 0.07, 0.05 and nd; chromium 0.08, 0.07, 0.08 and 0.01; for vanadium 0.06, 0.07, 0.02 and nd; manganese 0.3, 0.5, 0.8, and 0.02; iron 8, 40, 100 and 5; aluminum 4, >30, 7 and 0.5; zinc 5, 4, 20 and 0.9; titanium 20, 0.7, 0.5 and 0.03; strontium 15, 1.5, 1.5 and 1.0; barium 30, 2, 1.5 and 0.06; sodium 20, 30, 30 and >30; calcium >100, 70, 35 and 15; and magnesium 10, 30, 100 and 70. Sharp differences were evident between individual species in a taxon.

2184. Vorob'yev, V.I. and V.F. Zaystev. 1975. Dynamics of some trace elements in organs and tissues of the rudd. Hydrobiological Jour. 11(2):57-60.

Concentrations are listed of Fe, Cu and Al in organs and tissues of rudd Scardinius erythrophthalmus, a teleost from the Volga delta. The order of Fe accumulation by organ and tissues is: kidney > gill fringe > spleen > liver > scales > swim bladder > muscle. In all organs except gill fringe, Fe accumulation was significantly higher in males. The order of Cu accumulation is: liver > scales > spleen > kidney > gill fringe > swim bladder > muscle. For Al, this was: kidney > scales > gill fringe > spleen > liver > swim bladder > muscle. Seasonal and sex-associated differences are discussed.

2185. Vostal, J. 1972. Transport and transformation of mercury in nature and possible routes of exposure. In Friberg, L.T. and J. Vostal (eds.). Mercury in the marine environment. CRC Press: 15-27.

Concentrations, chemical species, sources, and biological half-life of mercury in various species of fish, aquatic mammals, and fish-eating birds from different geographical areas are reviewed.

2186. Voyer, R.A. 1975. Effect of dissolved oxygen concentration on the acute toxicity of cadmium to the mummichog, Fundulus heteroclitus (L.) at various salinities. Trans. Amer. Fish. Soc. 104:129-134.

Fish acclimated to test salinities ranging between 10 and 32^{o}/oo were subjected to dissolved oxygen levels between 4 mg/l and saturation. Regardless of salinity and oxygen regimen, mean LC-50 (96 hr) values for Cd^{2+} ranged between 52 and 92 mg/l.

2187. Voyer, R.A., P.P. Yevich and C.A. Barszcz. 1975. Histological and toxicological responses of the mummichog, Fundulus heteroclitus (L.), to combinations of levels of cadmium and dissolved oxygen in a freshwater. Water Research 9:1069-1074.

LC-50 (96 hr) values for the mummichog, a euryhaline estuarine teleost, in freshwater ranged upward from 1.3 to about 3.0 mg cadmium/l at 2.3 and 8.5 mg dissolved oxygen (DO)/l, respectively. Mortality data showed factors examined were interdependent and that Cd x DO and Cd x time interactions were significant (P <0.01). No histopathology was evident at 3 mg Cd/l. Mummichogs exposed to 25 mg Cd/l at 20 C and 8.5 mg DO/l showed no histopathology after 5.5 hrs; at 6.5 hrs necrosis, mucosal sloughing of gills, and damage in nasal passage and buccal cavity tissues were evident.

2188. Waldichuk, M. 1974. Some biological concerns in heavy metals pollution. *In* Vernberg, F.J. and W.B. Vernberg (eds.). Pollution and Physiology of Marine Organisms. Academic Press, New York: 1-57.

Current research on toxicity, bioaccumulation, and physiological effects of selected heavy metals on marine biota is reviewed. Elements discussed include Al, Sb, As, Ba, Be, Bi, Cd, Cr, Co, Cu, Fe, Pb, Mn, Hg, Mo, Ni, Rb, Ag, Te, Th, Ti, U, V, and Zn, with special reference to stimulatory concentrations for algae, bioconcentration by fish and macroinvertebrates, and toxicity to crustaceans, molluscs, and fish. A list of 118 references is appended.

2189. Walker, G., P.S. Rainbow, P. Foster and D.J. Crisp. 1975. Barnacles: possible indicators of zinc pollution? Marine Biology 30:57-65.

Three species of barnacles (*Balanus balanoides*, *Elminius modestus*, *Lepas anatifera*) from several different sites accumulated zinc at levels from 138 to 3438 mg Zn/kg wet wt. Seventy-five to 88% of total Zn in barnacles was in soft tissues with 45 to 65% of total Zn in organism associated with gut and associated parenchyma. Zinc accumulated in gut was in the form of discrete concentrically layered granules, mainly within parenchyma cells which surround the gut; these granules probably are an insoluble Zn salt. Concentration factors for tissues associated with gut remained relatively constant for barnacles from different localities at 0.71 to 1.5 x 10^6 g Zn/g dry wt x g Zn/g seawater and suggests that gut Zn levels conform closely to environmental Zn levels.

2190. Walker, G., P.S. Rainbow, P. Foster and D.L. Holland. 1975. Zinc phosphate granules in tissue surrounding the midgut of the barnacle *Balanus balanoides*. Marine Biology 33:161-166.

Chemical composition of inorganic granules found in parenchyma cells surrounding the midgut of adult barnacles was found to be 38% Zn, 48% PO_4^-P, 5% Ca, 1% Fe, 1% Cu, 4% Mg, and 2% K. Results indicate that most trace metals entering barnacles are excreted except Zn, which primarily accumulates as insoluble zinc phosphate granules. These may be the end product of a detoxification process.

2191. Walker, G.C. and D.J.D. Nicholas. 1961. An iron requirement for a dissimilatory nitrate reductase in *Neurospora crassa*. Nature 198:141-142.

Neurospora grown at low oxygen tensions dissimilates nitrate. Under these conditions nitrate reductase is dependent on Fe and Mo for maximum activity. Deficiencies of either Fe or Mo at the 2-day stage of growth reduced nitrase reductase activity to 21% and 61% of normal activity. After 5 days growth, only Mo deficiency depressed nitrate reductase activity (by 43%). Enzyme activity at 5 days growth was not affected by Fe deficiency. Lack of Cu, Mn, or Zn did not decrease nitrate reductase activity at any stage of growth.

2192. Walker, J.B. 1954. Inorganic micronutrient requirements of *Chlorella*. II. Quantitative requirements for iron, manganese and zinc. Arch. Biochem. Biophys. 53:1-8.

Quantitative inorganic micronutrient requirements of *Chlorella pyrenoidosa* for Fe, Mn, and Zn were determined by obtaining plots of yield versus amount of added micronutrient in media devoid of added chelating agents. For growth of one g of dried *Chlorella*, a minimum of approximately 30 μg Fe, 2.5 μg Mn, and 4.5 μg Zn are required under the test conditions. In presence of ethylenediaminetetraacetic acid (EDTA), much larger quantities of all required micronutrients except Fe must be supplied for a defined yield; Fe requirement is same in presence or absence of EDTA. In absence of EDTA, Fe added in form of potassium ferricyanide was up to 2X as effective for growth per unit Fe as was iron in form of ferrous sulfate; this advantage was most marked in alkaline solutions. Both iron sources were equally effective in presence of EDTA.

2193. Walker, J.D. and R.R. Colwell. 1974. Mercury-resistant bacteria and petroleum degradation. Appl. Microbiol. 27(1):285-287.

Concentration of Hg in water and sediment, and in oil extracted from water and sediment, was determined for samples collected in Colgate Creek, located in Baltimore Harbor of Chesapeake Bay. Bacterial populations of samples studied had maximum tolerances of 4 to 60 mg HgCl/1 and can degrade oil, suggesting that these bacteria are significant factors in oil degradation in Colgate Creek. Concentration of Hg in sediment oil was 2795 mg/kg, and 2960 mg/kg in water-borne oil; by contrast, an oil-free sediment contained 0.67 mg Hg/kg and oil-free water <0.01 mg Hg/kg.

2194. Wallen, I.E., W.C. Greer and R. Lasater. 1957. Toxicity to *Gambusia affinis* of certain pure chemicals in turbid waters. Jour. Sewage Industrial Wastes 29(6):695-711.

Toxicities to mosquito fish of 86 chemicals commonly found in oil refinery wastes were determined in turbid pond water. LC-50's (96 h) in mg/l for some metal compounds were: 133 for $AlCl_3$; 1,640 for $BaCl_2$; 75 for $CuSO_4$; 74 for $FeCl_3$; 240 for $Pb(NO_3)_2$; 16,500 for $MgCl_2$; 920 for KCl; and 17,550 for NaCl. Effects of various soil suspensions were also examined.

2195. Wangersky, P.J. and O. Joensuu. 1964. Strontium, magnesium and manganese in fossil foraminiferal carbonates. Jour. Geology 72:477-483.

Deep sea foraminiferal cores from the Caribbean and Atlantic Ocean were analyzed for Sr, Mg and Mn. Concentration of Sr was uniform in all cores. The distribution of Mg was more variable both within and between cores. In all 3 cores there are direct correlations between Mn and depth, implying a shift of Mn into the coarse fraction from some other phase of the sediment.

2196. Ward, A. and R.G. Wetzel. 1975. Sodium: some effects on blue-green algal growth. Jour. Phycol. 11:357-363.

Anabaena cylindrica with no Na^+, suffered from decreased rates of acetylene reduction, ^{14}C assimilation, excretion of organic C as well as lower concentrations of chlorophyll a and particulate organic C when compared to cultures supplied with 5, 10, and 50 mg Na^+/l. Na-deficient algae released extracellularly a higher percentage of previously fixed C as organic C. No differences in any parameter measured were demonstrable among cultures grown with 5, 10, and 50 mg Na^+/l. Nitrate concentrations of 20 mg NO_3^-/l resulted in decreased rates of acetylene reduction and heterocyst numbers in Na-sufficient and Na-deficient cultures; however, decreased cellular Na content at high NO_3^- levels occurred only in N deficient cultures. Higher percentages of excreted organic C occurred with increasing NO_3^- concentrations in Na deficient cultures. Addition of 5 mg Na/l to natural bluegreen populations resulted in increased C fixation, but addition of 50, 100 or 200 mg Na/l elicited no response. Since Na concentrations of SW Michigan lake water at *ca.* 5 mg Na^+/l was sufficient for growth, Na is not assumed to be limiting under most natural conditions.

2197. Ward, E.E. 1966. Uptake of plutonium by the lobster, *Homarus vulgaris*. Nature (London) 209:625-626.

Lobsters were held in aerated, filtered seawater at 9-12 C containing 6.5 x 10^{-2} μCi/l of plutonium-239 for up to 220 days. When lobsters molt, the soft shell, gills, hepatopancreas and flesh contained relatively less Pu-239 than normal animals, while cast shell has $\sim$2X that of shell of intermoult lobster; calcifying shells rapidly accumulated Pu-239. The calcified skeleton (43% total wt of lobster) contains 89% of total Pu; whereas hepatopancreas has 4.6%; and flesh (28.7% total body wt) contains only 1.2%. Concentration factor for lobster flesh is 3, which is equal to cf of fish *Sarda lineolata*.

2198. Waterman, A.J. 1937. Effect of salts of heavy metals on development of the sea urchin, *Arbacia punctulata*. Biol. Bull. 73: 401-420.

The following concentrations of metals, as chlorides, prevented gastrulation when embryos were exposed during blastula stage: Ni 90.7 mg/l; Al 30.4 mg/l; Cd 92 mg/l; Cu 1.57 mg/l; Zn 2.4 mg/l; Zn (as sulphate) 2.03 mg/l; Zn (as acetate) 1.84 mg/l; and Hg 0.092 mg/l. Few gastrula developed at 14.9 mg/l Pb. No effect occurred at 8.8 mg/l Fe, the highest concentration tested. All controls developed to the young plutei stage during the same 13.5-17 hr test period.

2199. Watling, H.R. and R.J. Watling. 1976. Trace metals in oysters from Knysna Estuary. Marine Poll. Bull. 7(3):45-48.

Metal residues in *Crassostrea gigas* cultured in a South African estuary, in mg/kg dry tissue, were: Zn 396; Cd 3.7; Cu 32; Fe 128; Mn 16; Ni 1.6; and Ag 1.9. For *C. margaritacea* these values were: Zn 886; Cd 2.5; Fe 57; Mn 2; Ni 1.6; and Ag 2.6. *Ostrea edulis* had concentrations, in mg/kg dry tissue, of: Zn 660; Cd 3.1; Cu 38; Fe 167; Mn 6; Ni 1.7; and Ag 6.4. Logarithmic regression coefficients relating Zn, Cd, Cu, or Fe contents (ug) to dry tissue (g) for the 3 oyster species ranged from 0.415 to 1.064, with most values <1.0. It was the intent of this study to create a baseline for comparison with future effects of industrial growth.

2200. Watling, H.R. and R.J. Watling. 1976. Trace metals in *Choromytilus meridionalis*. Marine Poll. Bull. 7(5):91-94.

Oysters *Crassostrea gigas*, from a bay and lagoon on the SW African coast had metal levels in mg/kg dry tissue of 424 for Zn, 9 for Cd, 33 for Cu, 1 for Pb, 12 for Mn, 1 for Ni, 1 for Co, and 4 for Bi. Mean sediment levels in mg/kg were 8.7 for Zn, 0.7 for Cd, 3.3 for Cu, 17 for Pb, 12 for Mn, 6 for Ni and 3 for Co. Ranges of mean metal levels in mg/kg dry tissue of mussels *Choromytilus meridionalis* collected from 3 sites were 73 to 113 for Zn, 1 to 8 for Cd, 7 to 14 for Cu, 2 to 5 for Pb, 9 to 11 for Mn, 2 to 3 for Ni, 2 to 3 for Co, and 5 to 6 for Bi. Metal concentrations were negatively correlated with size. Females had higher Cu, Mn and Zn residues, but lower Pb and Bi than males of comparable size. Cu and Mn levels, and Pb and Bi contents were correlated, and all 4 were correlated with Zn. In mussels, concentrations of Fe, Ag and Cr were 60, 0.3 and 1.4 mg/kg dry wt, respectively.

2201. Watson, T.A. and B.A. McKeown. 1976. The activity of Δ5-3β hydroxysteroid dehydrogenase enzyme in the interrenal tissue of rainbow trout (Salmo gairdneri Richardson) exposed to sublethal concentrations of zinc. Bull. Environ. Contamin. Toxicol. 16(2):173-181.

Effects of exposure of adult trout for 50 days to 3 sublethal concentrations of zinc (0.248, 0.528 and 1.14 mg/l) on Δ5-3β-hydroxysteroid dehydrogenase (Δ5-3βHSDH) enzyme activity in the head kidney tissue was investigated. Zinc-exposed trout showed a greater degree of Δ5-3βHSDH activity compared to controls. Increase in enzyme activity is associated with stimulation of pituitary-interrenal axis by zinc stress.

2202. Webb, D.A. 1939. Observations on the blood of certain ascidians, with special reference to the biochemistry of vanadium. Jour. Exp. Biol. 16:499-523.

Vanadium chromogen in blood of several species of Ascidians was examined. Vanadium, in g/kg organic dry wt, was 0.4 for Ciona, 1.1 to 1.8 for Ascidia, 0.04 for Dendrodoa and <0.02 for Botryllus, Botrylloides, Tethyum and Microcosmus. Vanadium chromogen is not a protein or porphyrin, but may be an association of V with a straight chain complex of pyrrol rings. Seawater concentrations are calculated to be sufficient for V uptake. It is concluded that presence of V is a primitive character which has been lost in more specialized families.

2203. Wedemeyer, G. 1968. Uptake and distribution of Zn^{65} in the coho salmon egg (Oncorhynchus kisutch). Comp. Biochem. Physiol. 26:271-279.

Zinc-65 uptake and accumulation was strongly pH dependent in chorion of intact egg. In isolated chorion it was constant at 6 x 10^{-3} μM/g over pH range 2-9. Zinc uptake was inhibited by Cu^{2+} in range 0-2 mg/l Cu^{2+} but facilitated above 2 mg/l. Malachite green, an azo dye, increased Zn permeability especially at concentrations above 1 mg/l. Zinc uptake also increased with increasing temperature. About 70% of total accumulated zinc was bound to chorion; about 26% was in perivitelline fluid, 2% in yolk, and about 1% in embryo. Temperature, pH, inhibitor and kinetic studies indicated that Zn uptake involves physicochemical sorption to chorion together with passive diffusion into yolk and embryo.

2204. Weigel, H.P. 1976. Atomabsorptionsmessungen von Blei, Cadmium, Kupfer, Eisen und Zink im Seston der Ostsee. Helgoländer wiss. Meersunters. 28:206-216. (In German, English summary)

Seston samples from 23 stations between Kiel Bight and Finnish Bay in the Baltic Sea, were analyzed for Pb, Cd, Cu, Fe and Zn. Mean values in mg/kg wet wt were: Pb, 123; Cd, 6; Zn, 733; Cu, 61; and Fe, 3535. In contrast to trace metal analyses for offshore seston, values for Pb and Cd in the Baltic Sea are very high and values of Zn, Cu and Fe, apart from local influences, agree well.

2205. Weis, J.S. 1976. Effects of mercury, cadmium, and lead salts on regeneration and ecdysis in the fiddler crab, *Uca pugilator*. U.S. Dept. Commerce, Nat. Ocean. Atmos. Admin., Fish. Bull. 74(2):464-467.

Autotomized fiddler crabs were placed in solutions of 0.1 or 1.0 mg/l Pb^{2+}, Hg^{2+} or Cd^{2+} for up to 28 days. Retardation of regeneration was a specific effect of Cd at both 0.1 and 1.0 mg/l with no deaths occurring. At 0.1 mg/l, Hg was neither toxic nor had any effect on growth of limb buds. But at 1.0 mg/l Hg caused almost total inhibition of limb growth and was toxic to 60% of crabs. Mercury inhibition of regeneration is probably associated with its toxic properties. Lead had no effect on regeneration rate at levels examined. Crabs exposed for 2 wks to 0.1 mg/l of Hg contained 0.026 mg Hg/kg whole wet crab; those subjected to 0.1 mg/l of Cd contained 0.50 mg Cd/kg; and those exposed to 0.1 mg/l of Pb absorbed 2.04 mg Pb/kg.

2206. Weis, P. and J.S. Weis. 1976. Effects of heavy metals on fin regeneration in the killifish, *Fundulus heteroclitus*. Bull. Environ. Contamin. Toxicol. 16:197-201.

Regeneration of amputated lower half of killifish caudal fin was observed during exposure to Hg, Pb or Cd salts at 25 C and 30^{o}/oo salinity. One mg/l Hg was lethal to all fish within 1 week. At 0.1 mg/l Hg, all died within 1.5 weeks. Fish in 0.1 mg/l Pb regenerated at slightly faster rates than controls. At all three doses of Cd (0.01, 0.1, and 1.0 mg/l), fin regeneration was retarded but effect was not correlated with dose. Cadmium affected initial healing and blastema formation; however, growth rates of experimentals and controls were equal.

2207. Weiss, R.E., P.L. Blackwelder and K.M. Wilbur. 1976. Effects of calcium, strontium and magnesium on the coccolithophorid *Cricosphaera* (*Hymenomonas*) *carterae*. II. Cell division. Marine Biology 34:17-22.

Effects of deficiencies of Ca and Mg, and Sr enrichment on cell division in alga were studied. Cell growth was reduced at 0.04 g Ca/l and absent at 0.02 g Ca/l and lower. Addition of Sr to media deficient in Ca enabled cells to divide, the effect increasing with Sr concentration. When 0.4 g Sr/l was added to media containing 0.004 g Ca/l, rate of division and final cell concentration were comparable to controls (0.4 g Ca/l); Sr was 20X more effective in this respect than Ca. Rate of growth was also examined at various Mg concentrations: cell division was absent, or nearly so, in Mg concentrations below 0.001 g/l; cell size increased progressively as Mg concentration decreased. However, low protein concentrations were evident in absence of Mg. In media lacking Mg, cells exhibited changes in ultrastructure including rounding-up and apparent fragmentation of chloroplasts,and increase in vacuole size. Number of mitochondria per cell section increased 2.9X in absence of Mg while total cross-sectional area remained the same, indicating fragmentation.

2208. Welander, A.D., K. Bonham, R.F. Palumbo, S.P. Gessel, F.G. Lowman, W.B. Jackson, R. McClin and G.B. Lewis. 1967. Bikini - Eniwetok studies 1964: Part II. Radiobiological studies. Univ. Washington Lab Radiation Ecology, Seattle, Wash. UWFL - 93:164 pp. + Appendix.

Eniwetok and Bikini Atolls, in the west central Pacific, were the site of approximately 60 nuclear or atomic explosions between 1946 and 1958. They were visited in 1964, to identify and document kinds and conditions of organisms present on reefs and islands. Bird populations consisted of 6 species of shorebirds which fed primarily on molluscs, crustaceans and insects found in and on the beaches and islands, and 7 species of seabirds which fed upon small fishes and squid. Shorebirds contained (in p Ci/g dry wt) Mn-54, Co-60 and Cs-137 in amounts of 0.074, 48 and 350, respectively. Seabirds had 2.5, 6.0 and 0 p Ci/g dry wt of Mn-54, Co-60 and Cs-137, respectively. Shorebirds contained the highest amounts of Cs-137 in muscle tissue (200 p Ci/g dry wt at Eniwetok and 630 p Ci/g dry wt at Bikini). Liver, kidney, gut and skin had lower, but comparatively high amounts of Cs-137, with bones containing the lowest amount. No Cs-137 was found in detectable amounts in any organs of seabirds. Highest amounts of radioactivity in seabirds were in liver and kidney, mostly Mn-54 and Co-60.

Cobalt-60 at concentrations up to 200 p Ci/g dry wt, was the primary radionuclide found in plankton samples. Other radionuclides in relative order of abundance are Ru-106, Co-57, Sb-125, Bi-207, Mn-54 and Cs-137. Zn-65 was not detected in any plankton samples. Cobalt-60 was the most abundant radionuclide and the only one found in all plankton samples. Algae contained in decreasing magnitude of activity: Ce-144, Co-60, Ru-106, Bi-207, Mn-54, Cs-137 and Sb-125. Cerium-144 was the most dominant radionuclide. Filamentous, vesicular, or succulent types of algae appeared to have higher concentrations of radioactivity than coralline types. Radioactivity levels in echinoderms, sponges, coelenterates and other invertebrate samples varied with locality and species but insufficient to be hazardous to these populations. Especially high concentrations of Co-60 (up to 66,000 p Ci/g dry wt) and Co-57 (up to 11,000 p Ci/g dry wt) were noted in clams. Cesium-137 was noted at 2,000 p Ci/g dry wt in land crabs. Radioactivity of crabs was higher in terrestrial than in the more aquatic species, whereas the opposite was true in the weeks following detonations. Invertebrate life exists in approximately the same abundance as before the testing, except within a 0.5 mile radius of the large detonations. Even in these areas, the reduction in invertebrate life resulted primarily from mechanical rather than radioactive causes. Radionuclide content of fish, given as the higher average of the two atolls in p Ci/g dry wt were: 24 for Co-60, 2.9 for Mn-54, 1.2 for Cs-137 and Zn-65, 1.1 for Co-57, 2.0 for Bi-207, and 0.038 for Ru-106. No Sb-125 was found.

Comparison of radioactivity in various organs or tissues of fish, showed that highest values of Co-60 were in liver or viscera which included entire alimentary tract, gonads, air-bladder and spleen); smaller amounts were in "remainder" (which included some bone, muscle, skin, gills, kidney, and nervous tissue); lowest values were in the skin, muscle, and bone. Biogeographical distributions of radionuclides are given and their implications discussed.

2209. Wells, H.W. 1961. The fauna of oyster beds, with special reference to the salinity factor. Ecol. Monog. 31(3):239-266.

In the Beaufort, N.C. area between 1955-1956 distribution of oyster associates was compared with physical factors, particularly salinity. Three hundred and three species representing annelids, bryozoans, coelenterates, crustaceans, echinoderms, teleosts, insects, platyhelminthes, protozoans, and molluscs were collected. Number of species declined upstream and bore a direct relationship to salinity conditions. Mortalities due to hurricanes and the subsequent recovery of oyster beds were followed. Twenty species were tested in the laboratory for tolerances to low salinities; ranking of their salinity death points was compared with their distribution in the Newport River. Only 2 species showed wide deviations from distribution expected on basis of their salinity death points. It is concluded that a great majority of the species of the oyster bed community are limited in their upstream penetration by salinity.

2210. Westernhagen, H.V. 1974. Incubation of garpike eggs (*Belone belone* Linne) under controlled temperature and salinity conditions. Jour. Marine Biol. Assn. U.K. 54:625-634.

Hatching rate of larvae from artificially fertilized eggs was maximal at 18 C and salinities between 15 and 33°/oo. Minimum temperature and salinity for viable larvae production was 12 C and 10°/oo.

2211. Westernhagen, H.V. and V. Dethlefsen. 1975. Combined effects of cadmium and salinity on development and survival of flounder eggs. Jour. Marine Biol. Assn. U.K. 55:945-957.

Eggs of Baltic flounder *Pleuronectes flesus* were incubated in cadmium-contaminated seawater (0, 0.1, 0.5, 1.0, 2.0, 3.0, 5.0 mg/l) at 4 salinities (16, 25, 32, 42°/oo). Cd concentrations of 1.0 mg/l and above caused the chorion of eggs to become soft and to burst on removal from water. Effects of Cd on embryonic survival and viable hatch were not dependent on salinity of incubating water but showed a straight salinity dependence with survival being 40 to 50% for 25 and 42°/oo, and 15 to 20% at 32 and 16°/oo, compared to 80-90% in controls. At all salinities, hatching rates and viable hatch were not adversely affected by Cd concentrations of up to 1.0 mg/l; 2.0, 3.0 and 5.0 mg/l of Cd caused marked decrease in hatching rates and viable hatch. Mean total length, eye and otic capsule diameter did not appear to be adversely affected by increasing cadmium concentrations in rearing medium. Highest malformation rates (bent and crippled larvae) were obtained at 3.0 and 5.0 mg/l and at 16°/oo S. Cd concentrations in mg/kg dry wt of eggs in 5.0 mg/l Cd were: 45 for 42°/oo, 60 for 32°/oo, 65 for 25°/oo (fertilization occurred), 87 for 25°/oo (no fertilization), and 90 for 16°/oo. Other Cd concentrations showed a similar trend: uptake increasing with decreasing salinity.

2212. Westernhagen, H.V., V. Dethlefsen and H. Rosenthal. 1975. Combined effects of cadmium and salinity on development and survival of garpike eggs. Helgolander wiss. Meeresunters 27:268-282.

Eggs of Baltic Sea garpike *Belone belone* were incubated in normal and Cd-contaminated seawater (0.05, 0.1, 0.5, 1.0, 2.0, 5.0 mg/l) at 15°/oo, 25°/oo, and 35°/oo S and 15 C. Embryonic heart beat and frequency of pectoral fin movements in prelarvae was greatly depressed at Cd concentrations >0.5 mg/l. Embryonic survival and viable hatch were unaffected in Cd concentrations of 1.0 and 0.5 mg/l, respectively. At high Cd concentrations (2.0 and 5.0 mg/l) there was greater embryonic survival and viable hatch at comparatively high salinities. Cadmium content of eggs was generally higher in lower salinities than in more saline water at comparable cadmium concentrations. Accumulation factors of Cd in eggs were inversely proportional to the ambient Cd concentration. Highest accumulation factors of more than 40 were recorded at 0.05 mg/l Cd. At high cadmium concentrations accumulation factors were about 5.

2213. Westernhagen, H.V., H. Rosenthal and K.-R. Sperling. 1974. Combined effects of cadmium and salinity on development and survival of herring eggs. Helgoländer wiss. Meeresunters. 26:416-433.

Eggs of autumn spawning Baltic herring Clupea harengus were incubated in Cd-contaminated water (0, 0.1, 0.5, 1.0, 5.0 mg/l) at 5°/oo, 16°/oo, 25°/oo and 32°/oo S. Effects of Cd on embryonic survival were salinity dependent with deleterious effects of Cd and developing herring embryos more pronounced in brackish water than seawater. Embryonic activity as a measure of viability decreased in Cd concentrations with decreasing salinity, with most pronounced effect of Cd at 5°/oo S. Egg diameter was never altered by Cd content of incubation water. In all salinities incubation time was shortened with increased Cd content of medium. At 5, 16, and 25°/oo S and 0, 0.1, 0.5 and 1.0 mg Cd/l, hatching rate was not significantly altered by Cd. High hatching rates of 85 to 99% occurred in all salinity-Cd combinations. At Cd levels of 5.0 mg/l, there was greater survival of embryos at salinities of 32 and 25°/oo than at 16 and 5°/oo. Percentage viable hatch was unaffected at 32, 25 and 16°/oo S and 0, 0.1, and 0.5 mg Cd/l. At 5°/oo only 1% viable hatch occurred at 0.5 mg/l; in 16°/oo, 61% viable hatch occurred at 1.0 mg/l Cd. No viable larvae were obtained in any salinity at 5.0 mg/l Cd. In all salinities mean total length decreased with increasing Cd concentration. Relative decrease in mean total length was minimum at 32°/oo S. At all 4 salinities, yolk sac volumes of newly hatched larvae increased with increased Cd concentrations, probably due to declining embryo activity. Cd concentrations (in µg Cd/egg) of eggs in 5.0 mg/l Cd were: 0.013 for 32°/oo, 0.019 for 25°/oo, 0.04 for 16°/oo and between 0.057 and 0.038 for 5°/oo. In general Cd content of eggs at any given Cd concentration increased with decreasing salinity.

2214. Wettern, V.M., D.W. Lorch and A. Weber. 1976. Die wirkung von blei und mangan auf die grünalge Pediastrum tetras in axenischer kultur. I. Speicherungsraten und beeinflussung des wachstums. Arch. Hydrobiol. 77(3):267-276. (In German, English summary)

Over the range 0 to 1.0 mg Mn/l, Mn concentration of axenic freshwater algae cultures correlated linearly with ambient Mn level. Maximum concentration factor was 73. All Mn concentrations stimulated growth. Addition of Zn had no influence on growth but promoted Mn uptake.

About 15% of bound Mn could be desorbed by a 10^{-3} M EDTA-solution. Pb was accumulated only in small amounts; uptake was independent of solution concentration; Pb concentrations of 0 to 1.5 mg/1 had no influence on algal growth.

2215. Whitfield, P.H. and A.G. Lewis. 1976. Control of the biological availability of trace metals to a calanoid copepod in a coastal fjord. Estuarine Coastal Marine Sci. 4:255-266.

Organic material present in natural waters and in sediments alters availability of Zn, Mn, and Cu to prefeeding stages of *Euchaeta japonica*. In the laboratory, survival decreased with a decrease in amount of u.v. photo-oxidizable material. Replacement of the material with a known chelating agent (EDTA) increased survival. Comparison of survival in untreated water with that in different EDTA concentrations provided an EDTA equivalent value and this was used to indicate the natural complexing ability of water. An EDTA equivalent value was also obtained for saltwater extracts of bottom sediments. Natural complexing ability of deep water increased after a major intrusion of deep water and decreased with increasing residence time. Complexing ability of saltwater extractable material in bottom sediments appears to be dependent upon nearsurface productivity.

2216. Wieser, W. 1967. Conquering terra firma: The copper problem from the isopod's point of view. Helgol. wiss. Meeresunters 15:282-293.

In marine isopods and amphipods, water flow maintained via ciliary or muscular movements provides >6X copper needed. Food therefore contributes little to copper supply. Extraction of copper from primary vegetable matter by intertidal species is difficult and possible only at high Cu concentrations. Author suggests that microorganisms will liberate Cu from its natural tightly bound state in decaying algae. The amount of copper stored in hepatopancreas increases with increasing dependence of the species on the terrestrial environment; intertidal species exhibit intermediate Cu values. Copper is more strictly relegated to storage cells of the hepatopancreas in terrestrial isopods than in marine or intertidal isopod species. But in marine forms, copper seems to be able to move more freely in an easily dissociable state between storage cells and other cells of the hepatopancreas.

2217. Willard, J.T. 1908. On the occurrence of copper in oysters. Jour. Amer. Chem. Soc. 30:902-904.

Two samples of oysters suspected of causing illness were examined for copper. They contained 2110 and 3020 mg Cu/kg dry wt, respectively. A total of 34 samples of fresh and canned oysters were then tested; these contained between 50 and 1700 mg Cu/kg dry wt. Author concludes that Cu is normally found in oysters but not in levels as high as those of original samples.

2218. Williams, L.G. 1970. Concentration of ^{85}strontium and ^{137}cesium from water solutions by Cladophora and Pithophora. Jour. Phycol. 6:314-316.

The alga Pithophora accumulated Sr-85 and Cs-137 by respective equilibrium concentration factors of 2106 and 1816 when 0.1 mg Ca and 0.1 mg K/1 were also present; c.f. were 853 and 1514 in 30.1 mg Ca and 0.1 mg K/1; 2314 and 600 in 1.0 mg Ca and 30.0 mg K/1; and 1713 and 513 in 30 mg Ca and 30 mg K/1. Corresponding concentration factors for another alga, Cladophora, were comparable.

2219. Wilson, K.W. and P.M. Connor. 1971. The use of a continuous flow apparatus in the study of longer-term toxicity of heavy metals. Int. Coun. Explor. Sea. C.M. 1971/E8:343-347.

Newly-molted brown shrimp Crangon crangon were more vulnerable to Cd and Hg than unmolted animals; smaller individuals were more sensitive. LC-50 (48 h) values for Hg or Cd was 5 mg/1; after 1500 hr tests, both metals were toxic at 0.005 and 0.05 mg/1, respectively.

2220. Windom, H., W. Gardner, J. Stephens and F. Taylor. 1976. The role of methylmercury production in the transfer of mercury in a salt marsh ecosystem. Estuar. Coast. Mar. Sci. 4:579-583.

A salt marsh estuary near Brunswick, Georgia, which received discharges of approximately one kg of inorganic Hg daily for 6 years, was studied in order to evaluate occurrence and production of methylmercury. The methyl form was not detected (<1 ng/g) in marsh sediments or in the dominant Spartina alterniflora vegetation, although the inorganic form was present in amounts up to 1.47 mg/kg dry wt, with variation due to distance from Hg source and Spartina plant part. Significant levels of methylmercury were present in primary consumers Littorina irrorata, and Uca sp. with concentrations up to 0.61 and 0.40 mg/kg dry wt, respectively. Assuming that these molluscs and crustaceans accumulated a significant percentage of methylmercury produced in the salt marsh ecosystem, then annual production is estimated at 50 mg/kg of total Hg in the upper 5 cm of sediment column.

2221. Winner, R.W. 1976. Toxicity of copper to daphnids in reconstituted and natural waters. U.S. Environ. Protect. Agen. Rept. EPA-600: 3-76-051, USEPA, Congdon Blvd., Duluth, Minn. 69 pp.

Toxicity of copper was compared for *Daphnia magna* cultured in reconstituted versus pond water and fed on trout-pellet *vs* vitamin-enriched algal foods. Effects of chronic Cu stress were highly variable when tested in reconstituted waters, and this was attributed to variability in quality of distilled water used. Vitamin enriched algal food proved excellent for maintenance of 6 species of *Daphnia* (*D. magna*, *D. ambigua*, *D. parvula*, *D. pulex*, *D. pulicaria* and *D. galeate-mendotae*), while animals reared on trout-granule food exhibited reduced longevity and greater sensitivity to Cu. The two largest species, *D. magna* and *D. pulex*, had 72 hr LC-50's of 0.086 mg Cu/l while the two smallest species, *D. parvula* and *D. ambigua*, had 72 hr LC-50's of 0.072 and 0.067 mg Cu/l. Acute toxicity of chromium was tested and the following 72 hr LC-50's, in mg Cr/l, were: *D. ambigua*, 7.7; *D. magna*, 42.1; *D. galeata*, 65.6; and *D. pulicaria*, 110.8. Maximum allowable toxicant concentration (MATC) was estimated to be 0.04 mg Cu/l for *D. magna*, *D. ambigua*, *D. parvula* and *D. pulex* in pond water-algal system when longevity was used as a criterion, and 0.01 mg Cu/l for *D. magna* tested in the trout-granule-pond-water system. MATC based on longevity was estimated to fall between 0.050 and 0.075 mg Cu/l for *D. magna* tested in unaerated, standard water and between 0.015 and 0.020 mg Cu/l in aerated standard water. Reproductive response to chronic Cu stress was more variable than longevity. *D. magna* did not exhibit reduction in mean brood size at any Cu concentration that reproduction occurred; a rise in reproduction rate was observed at concentrations of 0.06 mg Cu/l and lower. No stimulatory effects of Cu on brood sizes in *D. pulex*, *D. parvula*, or *D. ambigua* were observed. *D. pulex* exhibited a significant reduction in mean brood size at 0.08 mg/l, *D. parvula* at 0.06 mg/l and *D. ambigua* at 0.04 mg/l. *D. parvula*, *D. pulex* and *D. ambigua* all exhibited restrictions in instantaneous rate of population growth (r) at Cu concentrations greater than 0.04 mg/l. Because of stimulatory effect of Cu on brood size in *D. magna*, r did not decline in this species until chronic Cu stress exceeded 0.06 mg/l. Application factors for *D. magna*, *D. pulex*, *D. parvula* and *D. ambigua* were 0.47, 0.57, 0.62 and 0.59, respectively.

2222. Winner, R.W. and M.P. Farrell. 1976. Acute and chronic toxicity of copper to four species of *Daphnia*. Jour. Fish. Res. Bd. Canada 33:1685-1691.

Respective LC-50 (72 hr) levels of copper in μg/l were 86.5, 86.0, 72.0 and 67.7 for *Daphnia magna*, *D. pulex*, *D. parvula* and *D. ambigua*. Survival of all species was affected at >40 μg Cu/l. Instantaneous rate of population growth (r) decreased at concentrations >60 μg Cu/l for *D. magna* and >40 μg Cu/l for other species. A decrease in brood size was observed at Cu levels >40 µg/l for D. ambigua and >60 µg/l for D. pulex and D. parvula. Reproduction of D. magna was inhibited at Cu levels >80 µg/l due to death of prereproductive females. All species of daphnids studied did not differ in susceptibility to chronic Cu stress.

2223. Wlodek, S. 1966. The behavior of ^{137}Cs in freshwater reservoirs, with particular reference to the reactions of plant communities to contamination. In Radioecological Concentration Processes. Proc. Inter. Symp., Stockholm, Apr. 25-29, Pergamon Press, N.Y.: 897-912.

Distribution of radiocesium in the ecological system due to radioactive fallout contamination was calculated to be 7% in water, 91% in sediments, and 3% in plants. In laboratory tank experiments the presence of filamentous algae, predominantly Ulothrix, and Nasturtium, both of which present large total surface areas to water, caused Cs-137, which normally attains low levels rapidly, to remain high in water for 2 weeks. Strong sediment contamination occurred within 24 hrs, with uptake of Cs increasing with organic content of sediments. When 3 levels of contamination were studied (4 uCi/l, 0.43 uCi/l, and 0.046 uCi/l), activity levels in water and in plants were proportional; therefore, levels of activity in plants may be used to characterize contamination in the environment. Distribution of Cs in plants was not uniform, with younger portions generally containing less Cs than older parts. Cs contamination was not found to affect biomass production of plants. Studies showed that water tends to give up its Cs quite rapidly to other parts of the ecosystem. Except for Ulothrix, which retained >60% Cs for a short period, plants generally play a modest part in Cs-137 accumulation, with bottom sediments being dominant receptors. Secondary contamination of water may occur due to strong agitation of plants, sudden changes of water level in reservoir, gentle agitation of bottom sediments, or death of plants. Results indicate that plants cannot be used to decontaminate waters, but can be used as bioindicators for contamination if previous histories and ecological conditions are considered.

2224. Wolfe, D.A. 1970. Zinc enzymes in Crassostrea virginica. Jour. Fish. Res. Bd. Canada 27:59-69.

Nearly all the zinc in oysters is bound either to soluble high-molecular weight proteins or to structural cellular components such as cell membranes. Oyster alkaline phosphatase is a zinc metalloenzyme, as indicated by in vitro inhibition studies with various metal-binding agents. Dialysis of soluble tissue extracts at pH 7-9 removes up to 96% of the total Zn without effect on alkaline phosphatase. If alkaline phosphatase is considered representative of the metabolic functions of Zn in oysters, most Zn accumulated by oysters must be superfluous to the animal's requirements.

2225. Wolfe, D.A. 1974. The cycling of zinc in the Newport River estuary, North Carolina. In Vernberg, F.J. and W.B. Vernberg (eds.). Pollution and Physiology of Marine Organisms, Academic Press, New York: 79-99.

A model was constructed for Zn flux that provides for primary production by phytoplankton and Spartina, conversion of part of this production to detritus by heterotrophic microorganisms, direct consumption of part of the phytoplankton production by zooplankton and herbivorous macrobiota, and consumption of detritus either directly or indirectly after microbial assimilation. The role of juvenile fish in the summer cycle of Zn within the estuary was estimated by this model to be: 1065 g/day ingested, 56 g/day assimilated, and 1009 g/day defecated. These figures are based on 3 fish species (menhaden, spot, and pinfish) which compose >40% of total nekton and epibenthic macrofaunal biomass in the estuary. A test of the hypothesis: only 10% detrital Zn is ultimately assimilated by microbiota and meiofauna thereby becoming available to macrofauna, was attempted through analysis of Zostera, benthic algae, and detritus for Zn. Mean values obtained were 84 mg/g dry wt (Zostera), 33 to 120 mg/g dry wt (algae), and 49 mg/g dry wt (detritus); results were inconclusive. Wolfe's model indicates that Zn is highly conserved and recycled approximately 16X per year. It also suggests that Zn occurs in more than one physicochemical form, with the form involved in biological cycling being distinct from that involved in sediment-water exchange. Additional flushing of dissolved and suspended Zn in the water column exerted little effect on biological fluxes around phytoplankton and detritus.

If the estuary is considered a closed system, turnover can be expressed as the fraction of exchangeable sediment Zn which is cycled annually through biota of the system. If the system extends to a depth of 1 m into sediments (the depth of Spartina root penetration), annual phytoplankton and Spartina incorporation of Zn (60.5 mg Zn/m^2 yr) would produce a turnover of about 0.8% per year. Thus, at least 100 years would be required to equilibrate any additions of Zn with the large reservoir represented by the deep sediment compartment. Surface sediments, however, are probably involved in a more rapid dynamic equilibrium with metals dissolved in the overlying and interstitial waters, due to a constant resuspension of fine silt, clays, and detritus, and to burrowing activities in the upper several cm of sediments. Turnover of Zn in the system can also be discussed as an open system, in terms of proportion of total Zn in the annual biological cycle which is exported annually from the system. Thus, the combination of commercial catch (0.19 mg Zn/m^2 yr), emigration of macrofauna (0.10) and flushing of zooplankton (0.011) and phytoplankton (0.3) accounts for ∿1% of total Zn incorporated annually by primary producers Spartina and phytoplankton (60.5 mg Zn/m^2 yr). This same estimate of biological export represents ∿1/6 of annual import in runoff from the watershed. Both considerations support the conclusion that the Newport River estuary has a great retentive capacity for Zn and approaches a closed system for biological cycling of this metal.

2226. Wood, J.M., F.S. Kennedy and C.G. Rosen. 1968. Synthesis of methylmercury compounds by extracts of a methanogenic bacterium. Nature 220:173-174.

Transfer of methyl groups from methylcobalamine to Hg^{2+} occurs naturally in mild reducing conditions. Anaerobic extracts of a methanogenic bacterium culture from canal mud at Delft, Holland, enhance this process, providing Me-Hg for incorporation into aquatic environments.

2227. Woodhead, D.S. 1973. Levels of radioactivity in the marine environment and the dose commitment to marine organisms. In Radioactive Contamination of the Marine Environment, IAEA-Sm-158/31, Vienna: 499-525.

Published data on levels of radioactive elements, Sb, Cs, Co, Eu, Fe, Pb, Mn, Ni, Nb, Pm, Po, Pu, K, Ra, Rb, Ag, Sr, Th, U, Y, Zn, and Zr, in seawater, the sea bed and marine biota from natural sources, fallout and waste disposal operations are reviewed. As a starting point for calculations of dose-rates to marine organisms data have several deficiencies. A complete set of data for all isotopes (natural and artificial) is not available for either a single species or even for groups of organisms. To calculate dose-rates, simple models have been employed to represent phytoplankton, zooplankton, mollusca, crustacea, and fish. Little known information on differential distributions within organisms and the prescription of standard volumes to each group present serious limitations. Within these limitations results of calculations show that, in a global context, dose-rates to marine biota from artificial radionuclides are of same order as those from natural background sources, and weapons-test fallout is the major contributor. Practice of marine disposal of radioactive waste leads to locally high dose-rates, but in population or global terms, dose-rate contribution is and will probably remain negligible.

2228. Wort, D.J. 1955. The seasonal variation in chemical composition of *Macrocystis integrifolia* and *Nereocystis luetkeana* in British Columbia coastal waters. Canadian Jour. Botany 33: 323-340.

Two species of seaweeds collected from Port Hardy and Vancouver, B.C. between October 1949 and September 1951 were analyzed for various inorganic and organic chemical species. Two year averages of copper, zinc, and iron in mg/kg dry wt (range), were: Macrocystis: Cu-fronds 59 (14-243), stipes 22 (4-87); Zn-fronds 97 (14-335), stipes 21 (10-34); Fe-fronds 562 (100-3250), stipes 125 (30-400). Nereocystis: Cu-fronds 46 (3-140), stipes 29 (7-70); Zn-fronds 424 (90-2800), stipes 74 (7-310); Fe-fronds 153 (4-420), stipes 124 (30-360).

2229. Wright, D.A. 1976. Heavy metals in animals from the north east coast. Marine Poll. Bull. 7(2):36-38.

Cadmium, zinc, copper and nickel levels in mg/kg wet wt in muscle of fish collected from the Northumberland coast of England ranged from 0.12 to 1.44 for Cd, 1.9 to 119.0 for Zn, 0.5 to 4.6 for Cu and 0.5 to 7.2 for Ni. Concentrations for gill, axial skeleton, skin, stomach wall, liver, fat body, kidney and gonad levels were also presented. Whole body metal levels in mg/kg wet wt for crustaceans ranged from 0.98 to 2.80 for Cd, 23.7 to 28.9 for Zn, 6.8 to 10.9 for Cu, and 6.5 to 9.8 for Ni. Values for selected crustacean tissues were also presented.

2230. Wurtz, C.B. 1962. Zinc effects on fresh-water molluscs. Nautilus 76(2):53-61.

One year after mine water discharge leading to 10 mg/l peaks of Total Heavy Metals (THM = Zn, Pb, Cu), molluscs were absent in a 19 km stretch of the NW Miramichi River, although levels below 1 mg THM/l prevailed at that time. However, macroinvertebrates representing 77 species and several phyla were present.

In laboratory studies adult pond snails Physa heterostropha exhibit LC-50 (48 hr) values of 3.62 mg Zn/l and 0.069 mg Cu/l at water hardness of 100 mg Ca CO_3/l, but 1.11 mg Zn/l at hardness of 20 mg Ca CO_3/l; juveniles were more sensitive to Zn than adults. Young Physa were about 3X more sensitive to Zn at 11 C than 32 C. Ramshorn snails Helisoma campanulatum exhibit an LC-50 (96 hr) value of 1.27 mg Zn/l at 22 C in hard water; however, unlike Physa, resistance was greater at 11 C. Helisoma, as was true for Physa, were more sensitive to Zn in softwater (20 mg Ca CO_3/l).

2231. Yamamoto, T., T. Yamaoka, T. Fujita and C. Isoda. 1971. Chemical studies on the seaweeds (26) Boron content of seaweeds. Rec. Oceanogr. Works Japan 11(1):7-13.

Boron content of 52 samples of 41 species of seaweeds from Wakayama Pref., Japan ranged from 16 to 319 mg/kg dry wt, with an average of 106 mg/kg. For ash, the range was 231 to 3038 mg B/kg with an average of 762.

2232. Yamamoto, Y., T. Fujita and M. Ishibashi. 1970. Chemical studies on the seaweeds (25) Vanadium and titanium contents in seaweeds. Rec. Oceanogr. Works Japan 10(2):125-135.

Average vanadium levels in mg/kg dry wt of brown, green, and red seaweeds, and limnetic weeds, were 3.1, 3.4, 2.8 and 1.1, respectively. For titanium these were 33.9, 40.9, 21.8 and 38.1, respectively.

2233. Yamanaka, S. and K. Ueda. 1975. High ethylmercury in river fish by man-made pollution. Bull. Environ. Contamin. Toxicol. 14 (4):409-414.

During heavy industrial ethylmercury pollution of the Jinzu River in 1969, ayu (Plecoglossus altivelis) and dace (Tribodon hakonensis) contained, respectively, 2.33 and 2.01 mg/kg ethyl-Hg and 2.72 and 4.65 mg/kg total Hg. In 1970, after ethyl-Hg input had ceased, ayu, which has a one year life cycle, had ethyl-Hg and total Hg concentrations of 0.2 and 0.3 mg/kg, respectively. However, dace, which lives for several years, did not drop to control levels until four years later, indicating a long biological half-life for Hg. Methylmercury levels in both species did not exceed 0.3 mg/kg during the 1969-1973 study period. Differences in contamination of fish with Hg from man-made and geological sources are discussed.

2234. Yoshimura, A., H. Tada, M. Sakai, T. Harada and K. Oishi. 1976. Distribution of inorganic constituents of Kombu blade - III Inorganic constituents of acceleratedly cultured ma-kombu at various growth stages. Bull. Jap. Soc. Sci. Fish. 42:661-664. (In Japanese, English summary)

The algae Laminaria japonica, in accelerated culture near Hakodate, Japan was analyzed for inorganic constituents. More than 70% of the ash consisted of Cl^-, K^+ and Na^+; these remained relatively constant during the study (April-July 1968). Nutrient ions such as Fe^{3+}, Al^{3+}, Ca^{2+}, and Mg^{2+} increased in June and decreased in July; Mn^{2+} decreased steadily; Cu^{2+} increased after decreasing in May. Groups, according to concentration factors, are: Al^{3+}, Cu^{2+}, Fe^{3+} and Mn^{2+} ($2 \times 10^5 - 10^4$); SiO_2 (2×10^2); K^+, Ca^{2+} (70-10); and Mg^{2+}, Cl^-, and Na^+ (2.3-1.6).

2235. Yoshinari, T. and V. Subramanian. 1976. Adsorption of metals by chitin. In Nriagu, J.D. (ed.). Environmental Biogeochemistry. Vol. 2. Metals Transfer and Ecological Mass Balances. Ann Arbor Sci. Publ., Ann Arbor, Mich.: 541-555.

Granular chitin was prepared from lobster shells and tested for adsorption of metals. Chitin absorbed 40 to 60% of metals in distilled water solution in 183 hrs, with accumulation independent of initial concentration of metals in the 1 to 16 mg/l range. Ca^{2+} initially taken up by chitin was released back to solution after 40 hr; pH of the solution decreased with increasing Ca retention by chitin suggesting that Ca^{2+} and H^{+} may interchange positions. Uptake rates of metals in 0.2 M, 0.4 M, and 0.6 M NaCl solutions were also determined. Initial concentrations of Mg^{2+} and Ni^{2+} had little effect on adsorption rates. As ionic strength decreased, amount of Mg^{2+} and Ni^{2+} adsorbed decreased linearly. Ca behaves similarly when initial Ca^{2+} concentration is 1 mg/l. Adsorption of Zn, Pb, Co, Cu, Mn and Fe is less dependent on variation of ionic strengths in the medium. Adsorption of a mixture of metals showed that a steady state was reached in 9 hrs with the following selectivity sequence in uptake of metals by chitin in double distilled water: Zn > Ni > Co > Cu > Pb. After 50 hrs, the following sorption sequence was recognized for metal uptake by chitin in double distilled water: Ni > Zn > Co > Cu > Pb > Fe = Mn > Mg > Ca. The general mechanism for chitin-metal complexation is discussed.

2236. Young, D.R. 1974. Cadmium and mercury in the southern California Bight. Summary of findings, 1971 to 1973. So. Calif. Coastal Water Res. Proj., 1500 E. Imperial Highway, El Segundo, Calif. 16 pp.

The Southern California Bight was monitored for mercury, cadmium, and DDT. Digestive glands of mussels Mytilus californianus contained Cd residues of 5.7 to 29 mg/kg dry wt, which were similar to levels found in specimens from sparsely populated islands offshore and indicating little regional contamination. Dover sole Microstomus pacificus trawled from the bight, had liver concentrations in mg/kg dry wt of 0.58 to 0.19 for Cd, and 0.11 to 0.19 for Hg, which are natural levels and again indicate no accumulation. Sediments and anthropogenic sources were also examined for Hg, Cd, and DDT contents.

2237. Young, D.R. and D.J. McDermott. 1975. Trace metals in harbor mussels. Ann. Rep. S. Calif. Coast. Water Res. Proj., El Segundo, Calif., June 30: 139-142.

Highest values recorded of selected metals in digestive gland of mussels Mytilus edulis from intertidal zones of San Diego Harbor and adjacent coastline, in mg/kg wet wt, were: 77.0 Cu; 7.4 Cr; 6.0 Ni; and 185.0 Zn. For gonads, maximum levels were 23.0 Cu; 3.0 Cr; 2.6 Ni; and 183.0 Zn. For muscle this was 53.0 Cu; 11.0 Cr; 14.0 Ni; and 172.0 Zn. Remainder contained upper values of 34.0 Cu, 3.4 Cr, 2.6 Ni, and 244.0 Zn. Cu and Zn levels in harbor mussels were about 9 and 3X greater, respectively, than coastal specimens; Cr and Ni levels were the same regardless of collection locale.

2238. Young, E.G. and W.M. Langille. 1958. The occurrence of inorganic elements in marine algae of the Atlantic provinces of Canada. Canadian Jour. Botany 36:301-310.

Concentrations in mg/kg dry wt of various elements in 11 species of green, red and brown algae, ranged from: 16,300 to 47,200 for Na; 23,100 to 71,100 for K; 2,500 to 24,000 for Ca; 0.3 to >2.0 for Ni; 0.09 to 6.25 for Co; 0.23 to 1.36 for Mo; 35 to 97 for Zn; 6 to 62 for Cu; 20 to 50 for Mn; and 2 to 58 for As. Chondrus crispus contained 8 mg Pb/kg dry wt. Thorough washing with tap water lowered content of ash, Na, K, and Si, but did not affect concentrations of other elements. No seasonal variation was detectable in concentration of trace elements in C. crispus. Differences in concentration were observed between frond and stipe in two species of Laminaria.

2239. Young, M.L. 1975. The transfer of ^{65}Zn and ^{59}Fe along a Fucus serratus (L.) → Littorina obtusata (L.) food chain. Jour. Mar. Biol. Assn. U.K. 55:583-610.

Zinc-65 was rapidly accumulated by F. serratus. The concentration factor (c.f.) of 10,768 had not stabilized at day 40, and remained high when algae were transferred to unlabelled seawater. Concentration of zinc in F. serratus is the result of a process of accumulation throughout the life of the plant. Iron-59 reached an equilibrium c.f. of 2000-2500 after 70 d. Some exchange of Fe-59 between labelled algae and seawater was observed, but it appears that Fe concentrations in F. serratus are largely dependent on age of tissue, as is the case for Zn.

In the laboratory, neither metal was accumulated up the food chain. The chain appears to be more important than direct uptake from water for accumulation of zinc and Zn-65, and iron and Fe-55 by L. obtusata. Results show that the food chain accounts for 60% of Zn-65 accumulation with an input of 1.1 ug Zn/g tissue/day to total tissue concentration of 46.7 ug Zn/g, and 42% of Fe-59 with an input of 0.91 ug Fe/g tissue/day to total tissue concentration of 34.6 ug/g. L. obtusata reacted similarly to Zn and Fe ingested in food, including similar rate of excretion from L. obtusata tissues.

Environmental samples of seaweeds gave Zn c.f. of 3600-9700 for Ascophyllum nodosum, 5200 to 12300 for F. serratus, and 4700 to 11300 for F. vesiculosus; c.f. varied with collection locale and with season in the case of Fucus sp. Analysis of environmental samples of L. obtusata indicated that it possesses some ability to regulate concentration of Zn in its tissues against changes in Zn content of food. This results in accumulation of Zn up the food chain when Zn content of food is low. L. obtusata from four sites contained up to 10X greater Fe residues than observed in the laboratory, possibly due to contamination by fine particulate matter trapped in the mantle cavity; no relation between Fe concentrations in L. obtusata and Fe in food was observed. The relevance of the results to radioecology and heavy metal pollution studies is discussed.

2240. Zaroogian, G.E. and S. Cheer. 1976. Cadmium accumulation by the American oyster, Crassostrea virginica. Nature 261:408-410.

Oysters in their third year were immersed in flowing raw seawater containing 5 μg of Cd^{2+}/l (range 4.7-5.3 μg/l), as $CdCl_2 \cdot 2\frac{1}{2}$ H_2O, for 40 weeks (November 1973 to August 1974). Whole body content of cadmium increased progressively from 2.72 mg/kg wet wt at start to 13.57 mg/kg wet wt after 40 weeks, a concentration considered potentially harmful to human health. Most of the increase occurred between weeks 28 and 40 when water temperatures ranged between 16.4 and 22.6 C. Control oysters held in seawater containing 0.1-0.2 μg Cd/l for the 40 week study always exhibited whole body residues between 1.69 and 2.81 μg Cd/kg wet wt.

2241. Zeitoun, I.H., D.E. Ullrey, J.E. Halver, P.I. Tack and W.T. Magee. 1974. Influence of salinity on protein requirements of coho salmon (Oncorhynchus kisutch) smolts. Jour. Fish. Res. Bd. Canada 31:1145-1148.

Six purified diets ranging from 30 to 55% protein were fed for 10 weeks to duplicate groups of coho salmon smolts maintained at 10 or 20°/oo salinity. Results demonstrated minimum protein requirements did not differ for fish at either salinity, and that weight gain and protein retention plateaued after 40% dietary protein was attained.

2242. Zeitoun, I.H., D.E. Ullrey and P.I. Tack. 1974. Effects of water salinity and dietary protein levels on total serum protein and hematocrit of rainbow trout (Salmo gairdneri) fingerlings. Jour. Fish. Res. Bd. Canada 31:1133-1134.

Seven separate diets ranging from 30 to 60% protein in 5% increments were fed for 10 weeks to trout maintained at 10 and 20°/oo salinity. Water salinity and dietary protein concentration did not significantly influence total serum protein. Hematocrit increased substantially with salinity (35.3% for fish at 10°/oo and 39.1% for those at 20°/oo), but different levels of dietary protein did not affect this parameter.

2243. Zeitoun, I.H., D.E. Ullrey, W.G. Bergen and W.T. Magee. 1976. Mineral metabolism during the ontogenesis of rainbow trout (*Salmo gairdneri*). Jour. Fish. Res. Bd. Canada 33:2587-2591.

Unfertilized oocytes and post yolk-absorption-stage larva of trout contained respective metal levels, in g/kg dry wt of: 0.9 and <0.01 for Ca; 1.4 and <0.05 for Mg; 3.4 and <0.01 for Na; 4.5 and <0.01 for K; 0.0761 and <0.00001 for Fe; 0.013 and <0.00001 for Cu; and 0.061 and <0.00005 for Zn. Derivation of Ca, Na, K, Fe, and Zn from water environment at postyolk absorption was estimated to be at least 70, 76, 45, 68, and 2%, respectively. All Cu in larva could have been derived from unfertilized oocyte.

2244. Zitko, V. 1975. Toxicity and pollution potential of thallium. Science Total Environ. 4:185-192.

Although world production of thallium amounts to 10 to 12 tons/yr, up to 48 t/yr of thallium may be present in wastes from zinc production in Canada alone. Atlantic salmon are relatively sensitive to Tl: the LC-50 value is 0.03 mg Tl/l. The following lethal doses in mg/l for thallium have been reported: 10 to 15 for rainbow trout, 60 for perch, 40 to 60 for roach (fish), 0.4 for tadpole, 2-4 for *Daphnia*, and 4 for *Gammarus*. Growth inhibition occurs at levels of 20, 390 and 200 mg/l for *Azotobacter*, *Proteus mirabilis*, and *Aspergillus niger*, respectively. LC-50's of fish for other metals include 0.2 mg Hg/l for stickleback, 0.09 mg ethylmercury/l for rainbow trout, 1.4 to 19 mg Cd/l for fathead minnow, 0.8 to 1.3 mg Pb/l for rainbow trout, 0.05 to 0.5 mg Cu/l for minnow and salmon, and 0.6 to 10 mg Zn/l for minnow and salmon. In Atlantic salmon, thallium had an accumulation coefficient (tissue conc mg/kg wet wt: water conc mg/l) of 130 in muscle, 170 in liver and 480 in gills. Combined effects with other naturally occurring chemicals, antidotes and sources of thallium pollution are discussed.

2245. Zitko, V. and W.V. Carson. 1975. Accumulation of thallium in clams and mussels. Bull. Environ. Contamin. Toxicol. 14(5): 530-533.

Clams *Mya arenaria* accumulated up to 6.03 and 12.45 mg/kg dry wt of thallium during exposure for 88 days to 50 and 100 μg/l Tl, respectively. After depuration for 30 days, thallium levels were <0.5 mg/kg dry wt. Mussels *Mytilus edulis* accumulated up to 4.26 and 6.33 mg Tl/kg dry wt during exposure for 40 days to 50 and 100 μg Tl/l, respectively. Thallium levels in mussels fell to <0.5 mg/kg 7 days after termination of exposure. Thallium levels in controls of both species were always <0.5 mg/kg dry wt. It was concluded that thallium is not an environmental danger to aquatic molluscs.

2246. Zitko, V. and W.G. Carson. 1976. A mechanism of the effects of water hardness on the lethality of heavy metals to fish. Chemosphere 5(5):299-303.

In flowing water bioassays with juvenile Atlantic salmon *Salmo salar*, toxicity of Zn is slightly decreased by increased concentrations of Ca and considerably decreased by Mg; but Mg and Ca do not affect biocidal properties of Cu and Cd. Authors stated that competition for active sites between Mg and Zn could account for effects of water hardness on Zn toxicity to fish. Mechanism of effects of hardness on toxicity of relatively weakly bound toxic cations, such as Be and Ni may be similar. The competition does not play a significant role in cases of very strongly bound cations, such as Cu and possibly Hg, or those acting on specific target sites, of which cadmium may be an example.

SECTION III

INDEX

Three indices are presented: INDEX-METALS, INDEX-TAXA, and INDEX-AUTHORS. Each index encompasses this volume and the two preceding volumes in this series, namely, Eisler, R. 1973. Annotated bibliography on biological effects of metals in aquatic environments (No. 1-567). U.S. Environmental Protection Agency Report R3-73-007: 287 pp.; Eisler, R. and M. Wapner. 1975. Second annotated bibliography on biological effects of metals in aquatic environments (No. 568-1292). U.S. Environmental Protection Agency Report 600/3-75-008: 400 pp.

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